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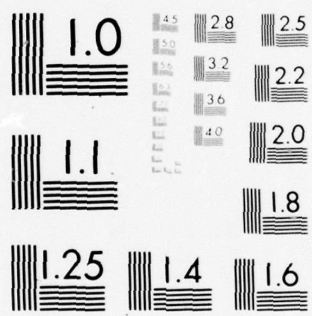
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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. ~~REPORT NUMBER~~ Current	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 9
4. ~~TITLE (and Subtitle)~~ LOW FREQUENCY RADAR SYSTEMS SHOULD REPLACE HIGH FREQUENCY RADAR SYSTEMS ON THE BATTLEFIELD TO OPTIMIZE THE ARMY'S GROUND SURVEILLANCE RADAR CAPABILITY. 6		5. ~~TYPE OF REPORT & PERIOD COVERED~~ Final Report ~~10 June 1977~~
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) ~~LaBay,~~ Paul H. M. ~~III~~ / LaBay ~~MAJ, USA~~ 10		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Student at the U.S. Army Command and General Staff College, Fort Leavenworth, Kansas 66027		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Command and General Staff College, ATTN: ATSW-SE		12. REPORT DATE 11 10 June 1977
		13. NUMBER OF PAGES 98
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 12 106p.
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Master of Military Art and Science (MMAS). Thesis prepared at CGSC in partial fulfillment of the Masters Program requirements, U.S. Army Command and General Staff College, Fort Leavenworth, Kansas 66027

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ground Surveillance Radar; Line-of-Sight Radar; Foliage Penetration Radar; Detection in a Foliated Environment; Detection in Built-Up Areas

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Current state-of-the-art technology provides the Army with two distinct types of radar to accomplish the ground surveillance mission. The first is a high frequency, line-of-sight system; the second is a low frequency, foliage independent system. To optimize its future ground surveillance radar capability, the Army must, in light of monetary and manpower constraints, choose that system which best fulfills its needs.

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20. This paper investigates the efficiacy of both systems to detect, acquire, and identify targets of military interest on the battlefield. It addresses both the machine and man-machine/human aspects of radar operation. The demonstrated capabilities of both systems are compared and evaluated to determine which system shows the greatest potential to optimize the Army's ground surveillance radar capability. The study concludes that low frequency radar systems are superior to currently fielded high frequency radar systems. It further recommends that the Army place priority effort into developing low frequency radar systems for future ground use.

LOW FREQUENCY RADAR SYSTEMS SHOULD REPLACE CURRENT HIGH FREQUENCY RADAR SYSTEMS ON THE BATTLEFIELD TO OPTIMIZE THE ARMY'S GROUND SURVEILLANCE RADAR CAPABILITY

A thesis presented to the Faculty of the U.S. Army Command and General Staff College in partial fulfillment of the requirements for the degree

MASTER OF MILITARY ART AND SCIENCE

by

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B.S., Canisius College, 1961

Fort Leavenworth, Kansas
1977

MASTER OF MILITARY ART AND SCIENCE

THESIS APPROVAL PAGE

Name of candidate: Major Paul H.M. LaBay III

Title of thesis: Low frequency radar systems should replace current high frequency radar systems on the battlefield to optimize the Army's ground surveillance radar capability.

Approved by:

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____________________, Member, Consulting Faculty

Accepted this 8th day of June 1977 by ____________________,
Director, Master of Military Art and Science.

The opinions and conclusions expressed herein are those of the individual student author and do not necessarily represent the views of either the U.S. Army Command and General Staff College or any other governmental agency.

ABSTRACT

One of the key requirements for U.S. maneuver forces to be able to win the first battle is the quick and accurate location of engaged enemy units in the battle area. At present and into the foreseeable future, ground surveillance radar will continue to provide the maneuver commander with a substantial part of this immediate intelligence information. Current state-of-the-art technology provides the Army with two distinct types of radar to accomplish the ground surveillance radar mission. The first is a high frequency, line-of-sight system; the second is a low frequency, foliage independent system. Because monetary and manpower constraints will limit the types and numbers of radar systems eventually deployed, the Army must choose that system which best fulfills its ground surveillance radar needs.

This paper investigates the efficacy of both systems to detect, locate, and identify targets of military interest under stated evaluative conditions. It addresses both the machine and the man-machine/human factors aspects of radar operation. The demonstrated capabilities of both systems are compared and evaluated to determine which system shows the greatest potential to optimize the Army's ground surveillance radar capability. The study concludes that low frequency radar systems offer the best practical solution to finding the enemy. It further recommends that the Army place priority effort into developing low frequency radar systems for future ground use.

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CHAPTER I

INTRODUCTION TO THE PROBLEM

BACKGROUND

"The Army's primary objective is to win the land battle--to fight and win battles, large or small, against whatever foe, wherever we may be sent to war."[1] The Army must be capable of defeating an enemy whose offensive and defensive doctrine stresses the maximum use of cover and concealment to achieve surprise or create opportunities to strike when and where its opponent is not prepared to fight.[2] "The art of the general is to achieve superiority whenever the foe presents himself."[3] To accomplish this in light of a constantly decreasing ground force, the Army is continually searching for new methods to exploit those superior elements of its combat power to defeat the enemy at the decisive point of battle.[4] U.S. Army doctrine and tactics fully recognize the preeminent importance of locating the enemy first in sufficient time to permit the maneuver commander to bring adequate combat power to bear at the point of decision to win the first battle.[5] Ground surveillance radars are one of the principal ways in which the maneuver commander "sees the battlefield" today.[6]

"The key to a proper doctrine is the correct understanding of the elements of one's superiority and the ability to apply them more rapidly than the opponent."[7] Current state-of-the-art technology provides two distinct types of radar to accomplish the ground surveillance mission. The first is a high frequency, unobstructed line-of-sight system and the second is a low frequency, foliage independent system. Because monetary and manpower constraints will continue to limit the amounts and types of radar systems fielded, the Army must select that radar system which best fulfills its ground surveillance needs within those constraints.[8]

HYPOTHESIS

Low frequency radar systems should replace current high frequency radar systems on the battlefield to optimize the Army's ground surveillance radar capability.

TASKS

To test this hypothesis the following questions are addressed:

1. What are the demonstrated capabilities, limitations, and vulnerabilities of each radar technology to detect and locate targets of military interest?

2. Which radar system maximizes the man-machine human factors equation?

3. Which radar system offers the best practical solution to "seeing the battlefield?"

4. Which system deserves the Army's priority development effort to enhance its future ground surveillance radar capability?

METHODOLOGY

Chapter I presents the background to the problem, states the hypothesis, and delineates the questions addressed to test the hypothesis. It also states the constraints and parameters under which this study was conducted. Chapter II presents a brief history of high and low frequency radar development and provides a brief description of each system's operational and design characteristics. Chapter III is a comparative analysis and evaluation of both systems to perform the combat surveillance mission on the battlefield. Chapter IV draws conclusions from the above results and tenders recommendations for future combat ground surveillance radar development.

SCOPE

This study investigates the efficiency of high and low frequency, moving target indicator ground surveillance radar technologies to acquire targets of military interest on the battlefield. The data base for this study is derived from test reports, combat evaluations, technical manuals and individual equipment performance reports on devices which are representative of each technology. The comparisons, measures

of effectiveness, and analysis use this same data base supplemented by the author's notes taken over a period of three years testing fielded implementations of both technologies.

This study addresses each radar system within the context of its primary mission: to detect, locate, and identify moving ground targets of military interest with sufficient accuracy to produce meaningful combat intelligence and to permit their accurate engagement by indirect fire means.[9] As such it is treated as a sensor used to aid the maneuver commander to better observe the battlefield. Therefore, its function remains essentially the same in either an offensive or defensive scenario, i.e., to warn the commander of enemy presence as soon as possible.

This study does not address detailed scientific or mathematical derivations of radar phenomena, but does present qualitative information on the general operational characteristics of each system.

ASSUMPTIONS

For the purpose of this paper only, the following assumptions are made:

1. Radar will continue to be one of the maneuver commander's principal means of ground surveillance in the foreseeable future.

2. Intermediate and long range low frequency radar systems can be built with approximately the same weight,

mobility, time of assembly, and ranging capability as their high frequency radar counterparts. Each would, however, be configured differently when deployed for operation. Although originally designed for short ranges, the Army has fielded a low frequency radar system in the ground-to-air role which exhibits the same ranging capabilities as the longest ranging high frequency ground radar system.[10]

3. Each system is operating at its full design potential and that all operators are fully qualified on their respective sets during the comparison discussion in Chapter III.

LIMITATIONS

Only unclassified data and documents available at the U.S. Army Command and General Staff College (USACGSC), from the Defense Documentation Center, and in the author's notes are used in this paper. Because of this restriction, electronic counter and counter-countermeasures are not discussed. However, simple radio frequency interference aspects of operation are addressed.

DEFINITIONS

The definitions contained in the Dictionary of U.S. Army Terms and The International Countermeasures Handbook are applicable in this study.[11] The following special definitions of generally accepted terms also apply:

1. *False alarm:* an indication by a system of the presence of a target of military interest when, in fact, no target of military interest is present.

2. *Target processing sequence:* the entire sequence of man-machine events that occur from the initial detection of a target to the final operator determined identification of the target by type and relative size.

CHAPTER I

ENDNOTES

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[3]David G. Chandler, The Campaigns of Napoleon (New York: The Macmillan Co., 1966), 143.

[4]Field Manual 31-100 (TEST) Surveillance, Target Acquisition and Night Observation (STANO) Operations, 20 May 1971 (Washington: Government Printing Office, 1971), para. 1-7, 3-1 to 3-12; see also MAJ George M. Hall, USAR, "The Genetics of the Battlefield," Military Review, November 1976 (Ft. Leavenworth: USACGSC, 1976), 49,50.

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Field Manual 31-35, Jungle Operations, 26 September 1969 (Washington: Government Printing Office, 1969), para. 6-13, 6-14; see also Reference Book 100-5-1, Operations, July 1976 (Ft. Leavenworth: USACGSC, 1976), 3-7, 4-3, 5-2 and 14-6; see also Jay Luvaas, ed. and trans., Frederick The Great on the Art of War (New York: The Free Press, 1966), 102; see also David G. Chandler, 147; see also Field Manual 31-100, Chapter 2; see also Reference Bo[illegible] 100-2, Volume III, Selected Readings in Tactics-Contingency Force Operations (Ft. Leavenworth: USACGSC, 1976), para. 8-1, 8-4, 8-12, 8-18 to 8-20; see also Reference Book 110-1, U.S. Air Force Basic Data, 1 July 1976 (Ft. Leavenworth: USACGSC, 1976), para. 4-7; see also Training Circular 101-5, Control and Coordination of Division Operations, April 1976 (Washington: Government Printing Office, 1976), 5,7.

[6] Reference Book 30-6, Intelligence Systems Factbook, 1 July 1976 (Ft. Leavenworth: USACGSC, 1976), Tables 1-3, 1-4, 1-5, 1-6 and 4-1; see also Reference Book 100-2, Vol. III, 8 to 10; see also Training Circular 30-23, Ground Surveillance Radar, 19 November 1976 (Washington: Government Printing Office, 1976), ii.

[7] Henry A. Kissinger, Nuclear Weapons and Foreign Policy (New York: Harper, 1957), 17.

[8] Jacques S. Gansler, "Reliability and Maintainability: DOD's Testing Factors," Commanders Digest, Vol. 19, No. 26 (Washington: Government Printing Office, 1976), 2; see also ibid., Donald H. Rumsfeld, "U.S. Defense Perspectives," Vol. 19, No. 18, 2 to 8; see also Thomas C. Steinhauser, "DOD Asks First Real National Budget Increase in Nine Years," Armed Forces Journal International, Vol. 112, No. 7 (Washington: Armed Forces Journal, Inc., 1975), 20 to 29; see also ibid., "Soviet Defense Spending Up 27% in Last 10 Years, U.S. Only 4%," 18,19.

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CHAPTER II

RADAR DEVELOPMENT AND DESIGN

PART ONE - H STORY

HIGH FREQUENCY RADAR DEVELOPMENT

Since its first tactical applications on the modern battlefield, radar has played an important role in extending the commander's ability to detect, locate, and track enemy targets far beyond human limits. This advantage was most aptly demonstrated in the early stages of the air war during the Battle of Britain. The British early warning radar network alerted the Air Defense Command well in advance of the size and direction of the Nazi air attacks from the continent.[1] Given this advantage, the British were able to concentrate their limited fighter forces at the critical place of battle to defeat, deflect, or significantly degrade the attacker's effectiveness. The radar network "multiplied severalfold the effectiveness of our [British] limited force and [gave] the enemy a bewildering misconception of its extent."[2] Radar also permitted the defenders to exercise highly flexible economy of force tactics for they knew in which areas they could reasonably take a prudent risk.[3] Unfortunately our own history provides a costly analog to the foregoing British success. On 7 December 1941, U.S. military authorities

disregarded the early warnings of incoming aircraft from radar picket stations deployed north of Pearl Harbor and we subsequently paid an inordinately high price in men and materiél for that error.[4] Accelerated development to extend this high frequency radar (HIFR) surveillance capability to the maneuver commander terminated with the end of World War II.

Since 1945, a graph of U.S. HIFR research, development, and acquisition activity closely resembles a large amplitude sinusoidal wave. The high activity periods of the Korean and Vietnam War contrast sharply with the neglible activity during the intervening years of nonconflict. Throughout these transition periods the Army recognized the advantage of ground surveillance radar and continued to develop HIFR systems for maneuver force use within fiscal restraints. Development concentrated primarily on HIFR technology because this approach offered the most feasible method of translating state-of-the art concepts into useable hardware with military potential.[5] Drawing upon the burgeoning electronic advances in the civilian sector, military developers improved equipment design, operational characteristics, and reduced the size of prototype equipments into more manageable packages adaptable to tactical maneuver use. Changes in U.S. military strategy during the early 1960's dictated a more balanced alignment between nuclear deterrent and credible ground deterrent forces.[6] This situation pumped new interest into radar development and from it evolved the current first line family of standard U.S. Army

ground surveillance radar systems. At present, this family consists of the AN/PPS-5A, AN/PPS-9, and AN/TPS-58 (RATAC) radar systems.[7] The short range AN/PPS-9 is soon to be replaced with the AN/PPS-15 which exhibits essentially the same operational and ranging capabilities as the AN/PPS-9.[8]

LOW FREQUENCY RADAR DEVELOPMENT

As the level of combat intensity increased in Vietnam, the main challenge at every echelon of command became "Find the enemy."[9] The enemy's extensive use of surprise, cover, and concealment to attack friendly forces by fire, ambush, and raid or defend by evasion highlighted the urgent need for better surveillance equipment.[10] The systems in use were not doing the job. "Very early in the Vietnam War, U.S. forces realized that finding the elusive enemy would tax intelligence resources to the limit."[11] The need for timely, accurate, adequate, and useable information, especially at the maneuver level, became critical if commanders were to be able to bring their superior firepower and mobile manpower resources to bear on the fleeting enemy.[12]

In response to this need DOD research and development agencies in conjunction with the civilian scientific community began to develop a wide range of surveillance devices to extend and improve the ground commander's reconnaissance, surveillance, and target acquisition capability in the stringently limiting Vietnamese environment. A plethora of

variably effective prototype equipments were funnelled through the Military Assistance Command Vietnam (MACV) Joint Research and Test Agency for combat evaluation.[13]

DOD programs, such as ENSURE and PROVOST,[14] also exploited new technologies which promised quantitative improvements in the commander's ground surveillance capability. Low frequency or foliage penetration radar (LOFR) was one of the first and most promising of these because it demonstrated a capability of detecting targets of military significance immersed in foliage.[15] In May of 1968, the U.S. Army Electronics Command published the technical guidelines and radar design characteristics for a man-portable foliage penetration radar system.[16] One year later the first prototype system was being operationally evaluated in combat. Initially deployed systems demonstrated a capability to reliably detect a single man walking target through 600 plus feet of dense rain forest. However, these sets also exhibited serious deficiencies in the areas of range, false alarm rate, angular resolution, and maintenance.[17] As this and other similar devices were deployed, researchers continued to improve upon the LOFR's operational characteristics. They devised new applications and incorporated the latest state-of-the-art electronic advances into the subsequent systems.[18] The end of the war brought a concomitant halt to this accelerated development. At present there are no standard low frequency ground surveillance radar systems in the Army inventory.

PART TWO - SYSTEMS DESCRIPTION

HIFR TARGETING SEQUENCE

The HIFR is tactically emplaced on the best available vantage point providing unobstructed line of sight (LOS) into the area of interest.[19] Under direct operator control or in a preset sector scan mode, the radar set incrementally sweeps the selected area with a thin beam of radiated energy.[20] In effect, the radar electronically maps the area within this narrow beamwidth out to its design range within LOS constraints (Figure 2-1). The reflected returns of the transmitted pulses from foliage and terrain, commonly called ground clutter, are presented to the operator as bright areas on the visual output (i.e., a scope) and as a low constant rumbling sound on the aural output (i.e., a speaker or headset). When this beam passes over a moving object of sufficient cross-sectional area and radial velocity with respect to the radar, the set automatically translates this difference in the mapped environment into a target indication. This is represented on the scope as a bright spot or "blip" outside the shaded clutter areas and on the headset as a distinctive change in the doppler audio tone. Discerning this change, the operator manipulates the set to place the beam directly on the target. This is accomplished when he maximizes the visual and aural target return indications.

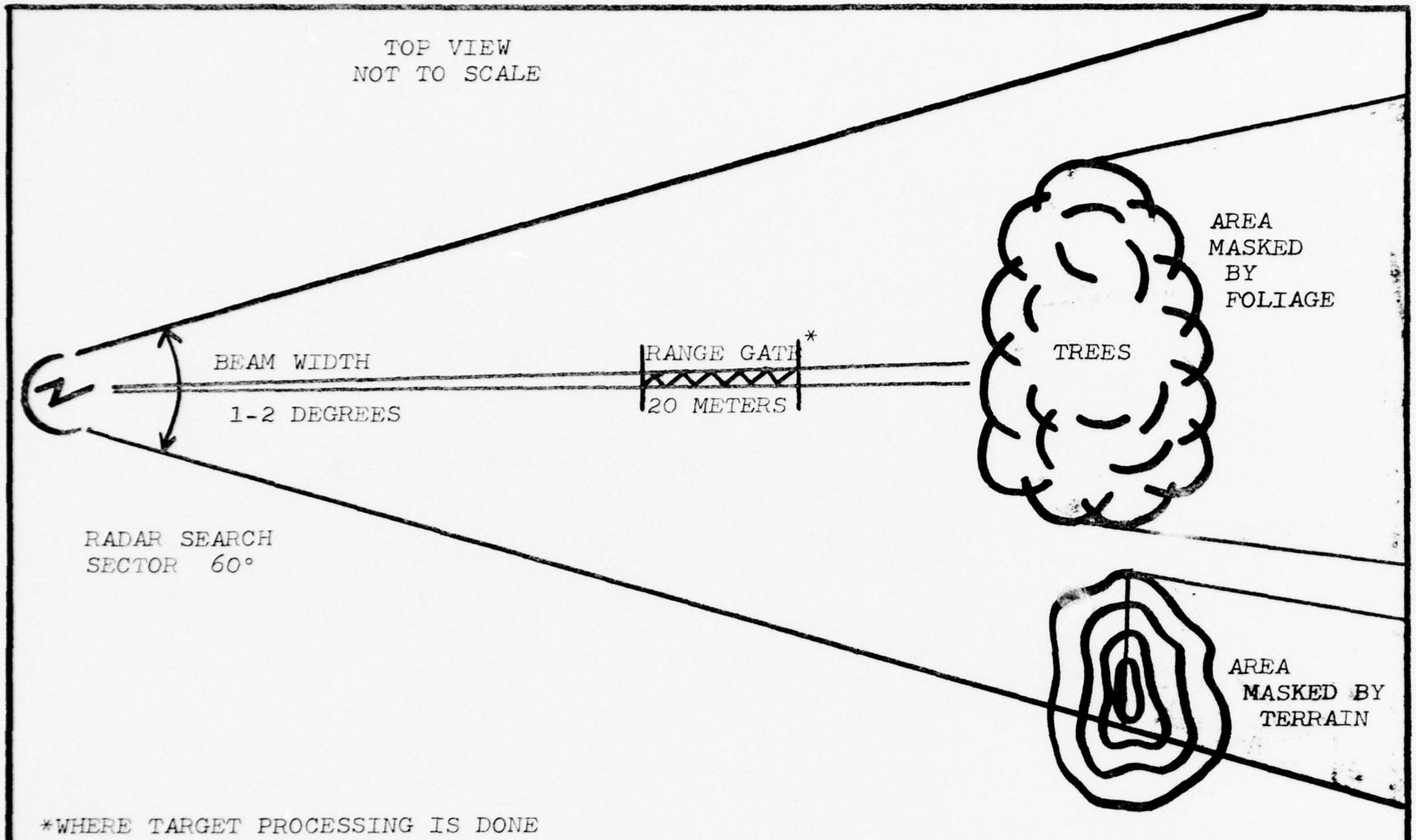


Figure 2-1. HIFR Surveillance Schematic.

By maintaining this maximized signal return in either the manual or automatic mode, he tracks the target as it traverses over the terrain. During the above sequence the operator is constantly evaluating the visual and aural displays to determine the type of target detected. Based on his best judgment and past experience, he makes a determination of target type and its relative size. If this track is broken for any reason, the operator must manually reinitiate search of the area, reestablish contact with the target, and repeat the target processing sequence.[21] Target data reporting procedures and alterations in the target search mode are dictated by the tactical situation and the unit's standard operating procedures.[22]

HIFR DESIGN CHARACTERISTICS

Each HIFR system is LOS dependent requiring unobstructed view of the target to detect it. Any intervening terrain or foliage feature which blocks LOS to the target will mask the target from the radar.[23]

The inherent design of HIFR systems provides an operator with the opportunity of detecting and processing only one target at a time.

HIFR systems can best be characterized as operator controlled radars. The operator is the key to effective set operation.[24] The set requires constant manual attention and judgmental skills on the operator's part to successfully complete a targeting processing sequence. The operator must

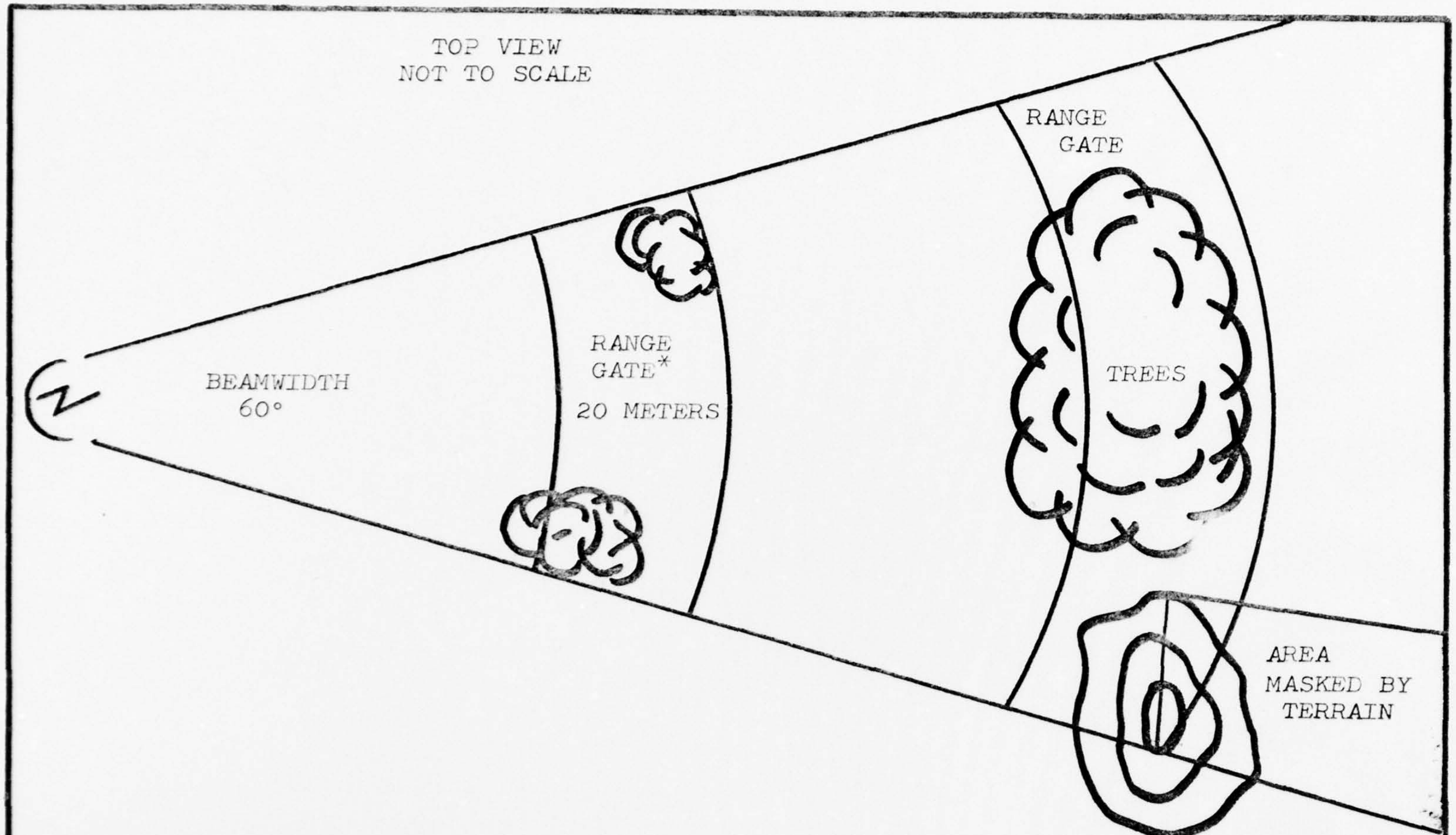
devote his full attention to the system. He must periodically make electronic adjustments to reduce interference and realign the antenna to insure maximum LOS observation. Because of the short amount of time a target is illuminated by the thin radar beam, the operator must have quick reflexes to establish contact with a possible target "blip," maintain continuous contact once detected, and reestablish contact with a lost target. Efforts to free the operator from some of this burden, such as the installation of an automatic target alarm on the AN/PPS-5A radar, have not proved satisfactory.[25]

HIFR electronic design, circuitry, and components generally reflect the technology of the early 1960's. Because their original design contains a balance in internal circuitry these sets are not amenable to the addition of components which disrupt this delicate internal balance or operate in a different mode than that originally designed into the set.[32]

LOFR TARGETING SEQUENCE

The LOFR system is tactically emplaced in the same manner as the HIFR except that the prime positioning consideration is ground clutter instead of a combination of ground and foliage clutter.[26] The operator manually selects the areas he wishes to search on the display using one available range gate for each area of interest.[27] He checks the internal electronic working condition of the set with the built-in test equipment (BITE) and activates the radar. The set

automatically scans a 60 degree wide, 20 meter deep band of terrain for each gate deployed at the ranges previously selected by the operator with a beam of near continuous radiated energy (Figure 2-2). The set can electronically cover the areas within these range gates at better than 1,000 times a second. Stationary ground and foliage clutter signal returns are electronically cancelled by the set. When a target penetrates into one of the deployed electronic range gates, the set senses this change in the mapped environment and produces an automatic visual and aural alarm of the target's presence. The automatic alarm consists of an audible buzzer tone and a series of lights indicating target direction with respect to the radar. These alarms, tied to a specific range gate, remain on until deactivated by the operator. Each range gate also has individual audio and visual presentations which permit the operator to process the target. The audio output, a translation of the target signal return down to human hearing range, is similar to that found in HIFR systems. The visual output is a scope and/or meter which measures relative target signal return strength from the deployed range gate. As the target progresses into the range gate (Figure 2-3, position "A") the audio output changes in tone and pitch while the meter readings increase in magnitude. When a target reaches the middle of the range gate (Position "B") the meter reading peaks and the target is physically located at the range indicated on the display panel. The operator then



*WHERE TARGET PROCESSING IS DONE.

Figure 2-2. LOFR Surveillance Schematic.

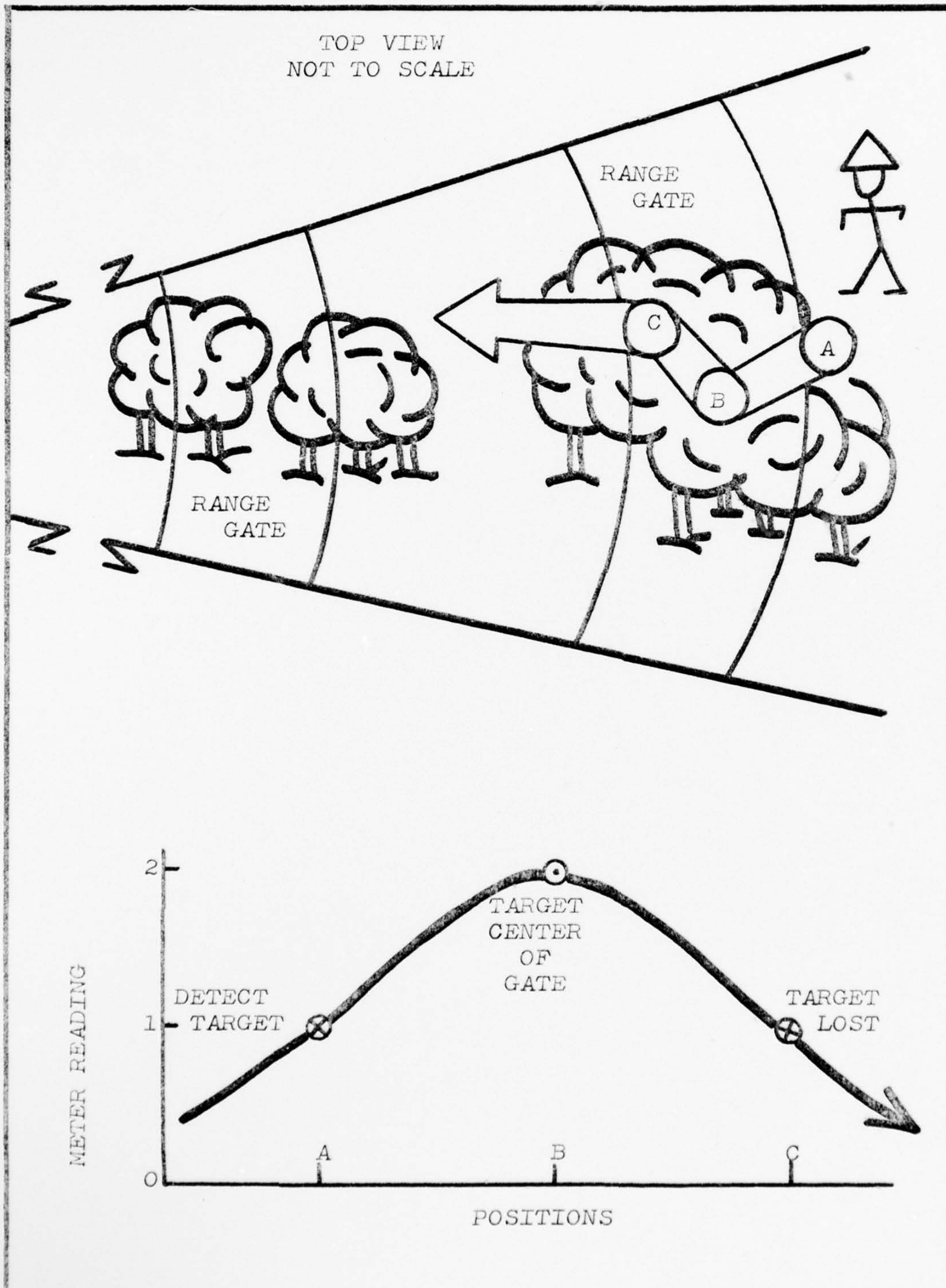


Figure 2-3. LOFR Targeting Sequence.

activates the azimuthal function of the set and determines the relative bearing to the target. The reverse occurs as the target travels out of the gate (Position "C"). From the distinctive audio doppler tone, the return signal magnitude, and the speed with which the target traveled through the gate, the operator estimates the target type and its relative size. The operator may then track the target, manipulating either range gate in the direction of target travel to insure electronic contact. He also has the option of tracking with a free range gate, leaving the gate which originally detected the target free to search for other targets. If target track is lost for any reason, the operator backs the range gate off a representative distance in the appropriate direction from the last contact position and waits for the target to reappear. The target information reporting procedures described in the HIFR target processing sequence are the same for this scenario.

LOFR DESIGN CHARACTERISTICS

LOFR systems are capable of detecting multiple targets simultaneously. The number that can be detected simultaneously is a function of the number of independent range gates designed into the system. Under present circumstances only one target can be effectively processed at a time because of space limitations of a single operator at the set. The most sophisticated set fielded had the capability of detecting up to 96 targets independently and processing three simultaneously.[28]

In this paper, a LOFR set with two independent range gates will be used in the subsequent discussion.

Although LOFR's are capable of detecting targets immersed in foliage they are not capable of detecting those same targets located behind a ground terrain mask. It is also noted that any foliage the radar must penetrate reduces its maximum effective range.[29] For example, if a LOFR is capable of detecting a target out to a range of 2 kilometers in a moderately foliated area, it can only detect that same target at 1,500 meters in a comparable densely foliated area.

Effective LOFR operation is a function of the target, foliage, and antenna heights as well as the classic free air radar equation limitations.[30] The only variable designers can influence to improve set operation is the antenna height. Therefore, LOFR's have characteristically high antenna masts of 30 to 50 feet. Also LOFR's should be employed in front of or at least 30 meters away from heavy foliage to eliminate a large immediate foliage clutter return.[31] If suitable positions are available, such as a high promontory with steeply falling away terrain, the LOFR can be positioned in the same manner as an AN/PPS-5.

Although LOFR systems place a small burden on the operator, the operator remains the key to effective set operation. The operator does not have to devote his full attention to the set. LOFR's incorporate advanced design circuitry such as balanced doppler signal processing to

automatically optimize set operation in its changing environment. The set automatically adjusts to the environment changes. In essence the set automatically performs the surveillance function. The operator is free to perform other tasks until the set alerts him to a potential target's presence.

SUMMARY

From the foregoing discussion one discerns that the two candidates offer not only a distinct difference in operating frequency but also in the technological approach, method, and potential in which each system addresses the ground surveillance and target acquisition problem.

Table 2-1 presents a comparison of these radar characteristics derived from the foregoing discussion. Figures 2-4 and 2-5 present photographs of the HIFR systems AN/PPS-5A and AN/TPS-58 respectively. Figure 2-6 presents the Multipurpose Foliage Penetration Radar, a LOFR system developed by the Army Land Warfare Laboratory. Figure 2-7 presents the Camp Sentinel Radar III, a LOFR system developed by Harry Diamond Laboratories.

Table 2-1. Comparison of Radar Characteristics.

ASPECT	HIFR	LOFR
Technology	Late 1950's/Early 1960's.	Late 1960's/Early 1970's.
Frequency Range	6 to 17 GIGAHERTZ (H,I,J, Bands).	250 MEGAHERTZ to 1.5 GIGAHERTZ (B,C,D Bands).
Targeting	One target at a time.	Multiple targets simultaneously; dependent upon number of independent range gates available.
Scan Rate	2.25 to 4.5 degrees per second.	Continuous within the entire area of the deployed range gates.
Environment		
Ground Mask	Cannot penetrate.	Cannot penetrate.
Foliage Mask	Cannot penetrate.	Can detect targets immersed in foliage; ranging capability decreased as the depth or density of foliage increases.
Operational Orientation	Heavily oriented on operator ability and manipulative coordination.	Machine oriented; machine performs the surveillance function automatically.
Operational Considerations	Must be positioned on prominent terrain with LOS into area of interest; only a small part of the search area is under direct observation at any one time.	Must be positioned to eliminate ground mask only. A relatively large, high antenna is susceptible to enemy observation; range is currently limited.

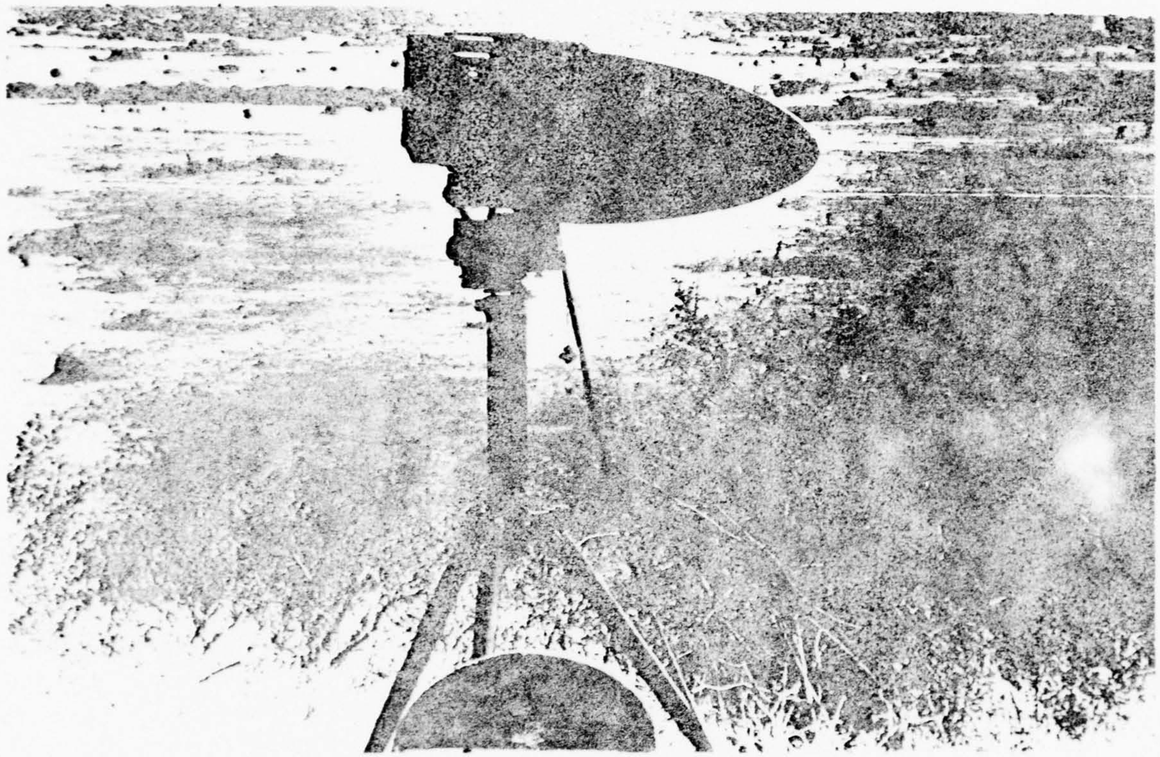


Figure 2-4. AN/PPS-5A Radar Set.

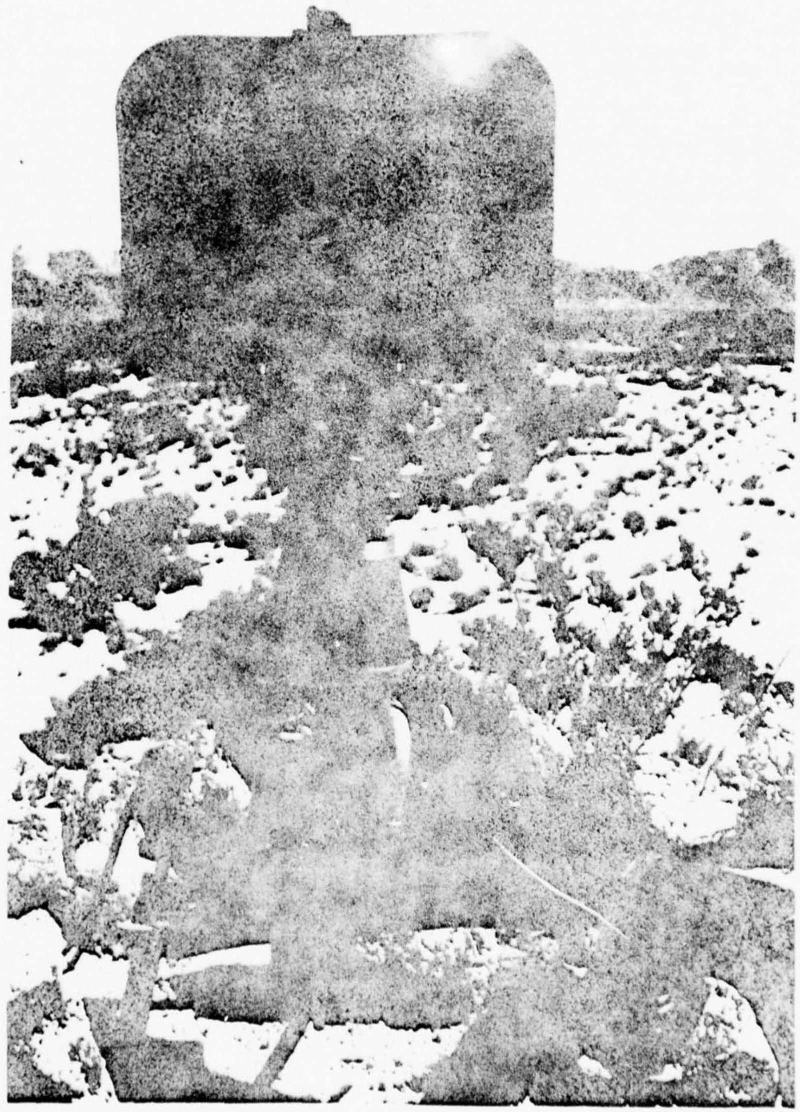


Figure 2-[illegible]. AN/TPS-58 (RATAC) Radar Set.

Figure 2-6. The Multipurpose Foliage Penetration Radar Set.

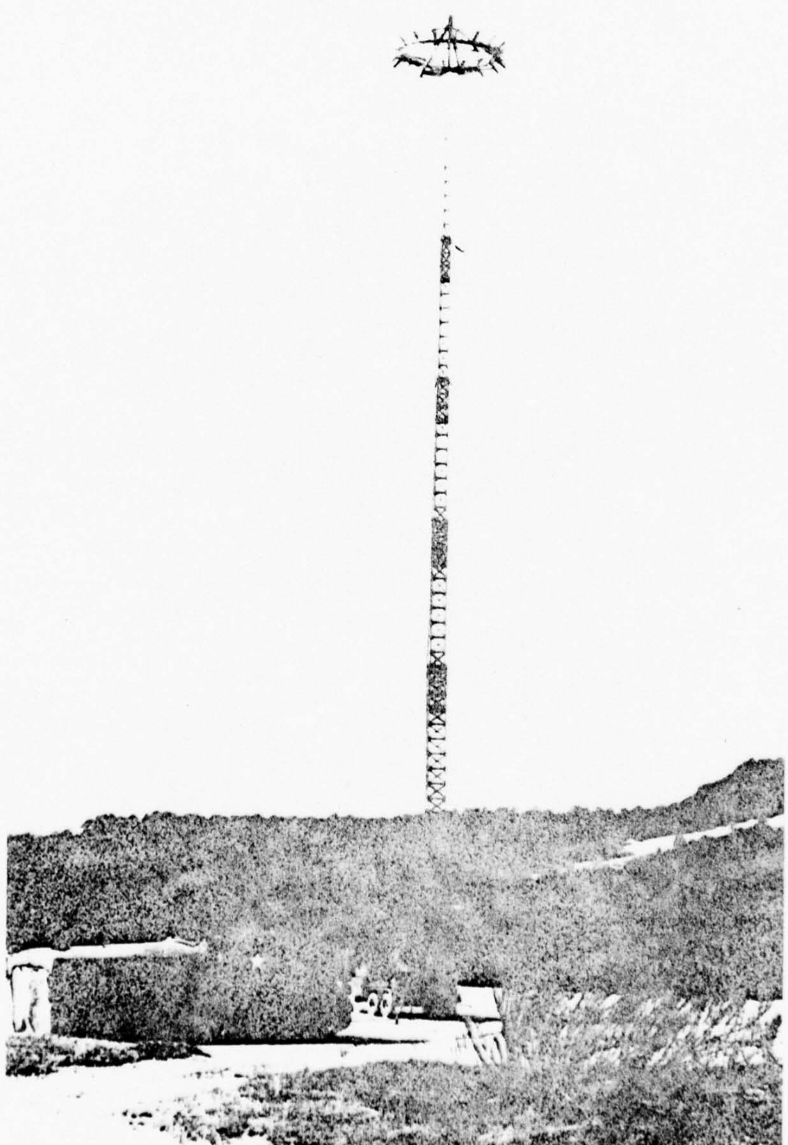


Figure 2-7. The Camp Sentinel Radar III Set.

CHAPTER II

ENDNOTES

[1]F. W. Winterbotham, CBE, The ULTRA Secret (New York: Harper and Row Publishers, 1974), 45, 48 to 50.

[2]Brigadier L. H. Harris, Signal Venture (Aldershot, England: Gale and Polden Ltd., 1951), 149.

[3]J. H. Crowther and R. Whiddington, Science at War (New York: Philosophical Library, 1948), 8, 9; see also Sir Robert Watson-Watt, The Pulse of Radar (New York: The Dial Press, 1959), Chapters 29, 30. This volume is a fine history of early radar evolution by a man who was intimately involved in its development and first tactical employment.

[4]Pearl Harbor Attack: Hearings before the Joint Committee on the Investigation of the Pearl Harbor Attack, Congress of the United States, 79th Congress, First Session (Washington: Government Printing Office, 1946), 69; see also Mark Skinner Watson, Chief of Staff: Prewar Plans and Preparations (Washington: Government Printing Office, 1950), 515, 516; see also A. A. Hoefling, The Week Before Pearl Harbor (New York: W. W. Norton and Co., Inc., 1963), 183 to 185; see also A. J. Barker, Pearl Harbor (New York: Ballantine Books Inc., 1969), 93 to 95; see also Gwenfread Allen, Hawaii's War Years (Honolulu: University of Hawaii Press, 1950), 1 to 3.

[5]Crowther and Whiddington, 19, 20.

[6]Maxwell D. Taylor, The Uncertain Trumpet (New York: Harper Co., 1960), 146 to 160; see also "Text of [NATO] Ministerial Council Communique," New York Times, 7 May 1962, 3; see also Jack Raymond, "NATO Atom Arms Policy," New York Times, 10 August 1962, 1.

[7]A general description of these systems is provided in Field Manual 31-100 (TEST), Surveillance, Target Acquisition and Night Observation (STANO) Operations, 20 May 1971 (Washington: Government Printing Office, 1971), B-71 (AN/TPS-58), B-75 (AN/PPS-5), and B-77 (AN/PPS-9); for a detailed description of individual radar capabilities and

operation see Technical Manual 11-5840-298-12, Radar Sets AN/PPS-5 and AN/PPS-5A, 1 June 1967 with changes (Washington: Government Printing Office, 1967) and Technical Manual 11-5840-348-12, Radar Set AN/TPS-58, 12 August 1971 with change 1 (Washington: Government Printing Office, 1971). Only contractor produced manuals are available on the AN/PPS-9.

8 Telephonic interview wi h COL Sammy J. Cannon, Battlefield Systems Integration Directorate, Headquarters, DARCOM, on 7 April 1977.

9 Joseph A. McChristian, MG, The Role of Military Intelligence 1965-1967 (Washington: Government Printing Office, 1974), 3; see also Lieutenant Colonel Albert N. Garland, USA, ed., Infantry in Vietnam (Ft. Benning: Infantry Magazine, 1967), 17.

10 John H. Hay, Jr., LGen, Tactical and Materiel Studies (Washington: Government Printing Office, 1974), 3,4.

11 Ibid., 5.

12 McChristian, 6 to 8; see also Lieutenant General Julian J. Ewell and Major General Ira A. Hunt, Jr., Sharpening the Combat Edge (Washington: Government Printing Office, 1974), Chapter V.

13 George S. Eckhardt, Command and Control 1950-1969 (Washington: Government Printing Office, 1974), 42; see also U.S. Army Materiel Command STANO Catalog, March 1970 (Washington: Government Printing Office, 1970), all.

14 ENSURE: Expedited Non-Standard Urgent Requirement for Equipment; PROVOST: Priority R&D Objective for Vietnam Operations Support.

15 Louis V. Surgent, Jr., Foliage Penetration Radar: History and Developed Technology (Aberdeen Proving Ground: Army Land Warfare Laboratory, 1974), 4,5, 17 to 19.

16 U.S. Army Electronics Command (ECOM) Technical Guideline Number R 580Z-004-68 (Ft. Monmouth: ECOM, 1968).

17 Man-Portable Foliage Penetration Radar-Final Report (Saigon: Army Concept Team in Vietnam (ACTIV), 1970); see also Base Defense Foliage Penetration Radar-Final Report (Saigon: ACTIV, 1970).

[18]G. Heidbreder and others, A Study of Radar Angel Phenomena (Santa Monica, CA.: Technology Service Corporation, 1971), iii, 1,2. The entire study deals with eliminating false alarm problems in foliage penetration radar systems; see also Alexander H. Riccio and Eric J. Isbister, Personnel Detection Radar (Littleneck, N.Y.: Hazeltine Corporation, 1969), 5 to 12, 32, 66, 85 to 92; see also William L. Emery, Moving Platform FOPEN Radar Prototype Development (Aberdeen Proving Ground: Army Land Warfare Laboratory, 1974), 1 to 19.

[19]Training Circular 30-23, Ground Surveillance Radar, 19 November 1976 (Washington: Government Printing Office, 1976), 9 to 12. The set operation portrayed represents a composite blending of all currently fielded HIFR Systems but most closely parallels that of the AN/PPS-5A radar. This system, by virtue of its projected widespread proliferation and tactical employment at maneuver level, is designed to provide the commander with the vast majority of his radar surveillance and target acquisition information at that level.

[20]Ibid., 1 to 8; see also Short-Range Surveillance Radar Set AN/PPS-5 (Deer Park, N.Y.: Airborne Instruments Laboratory, undated), all. For an excellent qualitative description of HIFR operation, see "RADAR," Collier's Encyclopedia, Vol.19 (New York: 1975), 593 to 598; see also "RADAR," Encyclopedia Americana, Vol. 23 (New York: 1975), 115 to 115j. For an excellent detailed description see Fred E. Nathanson, Radar Design Principles (New York: McGraw-Hill Book Co., 1969), 71 to 83; see also "RADAR," Encyclopedia Britiannica, Vol. 16 (Chicago: 1971), 993 to 1019. See also "RADAR," Encyclopedia of Science and Technology, Vol.11 (New York: 1972), 212 to 221.

[21]Nathanson, 93 to 103; see also Encyclopedia Britiannica, Vol 16, 1002 to 1006, 1018.

[22]Reference Book 30-6, Intelligence Systems Factbook (Ft. Leavenworth: USACGSC, 1976), A-9. See also Training Circular 30-23, 2.

[23]Ibid., 4-2; see also Field Manual 31-100 (TEST), 3-7; see also Hay, 33,34; see also Training Circular 30-23, 1,9 to 12.

[24]Ibid., 4-2.

[25]Captain George W. Gehr, AN/PPS-5 Improvement Kit and R2010 Battlefield Surveillance Radar Test Report (Ft. Hood: MASSTER, 1972), iv.

[26] The set operation described very closely resembles that of the Camp Sentinel Radar III or the Army Land Warfare Laboratory (ALWL) Multipurpose Foliage Penetration Radar (M-FOPEN), both of which were combat evaluated in RVN and field tested in CONUS and Hawaii respectively. For a description of the M-FOPEN System, see Louis V. Surgent, Jr., Evaluation of the Multipurpose Foliage Penetration Radar (M-FOPEN) in Hawaii (Aberdeen Proving Ground: ALWL, 1974), 6, A-1 to A-3.

[27] Ibid., A-3; see also Major Paul H. M. LaBay III, (C)Camp Sentinel Radar III (CSR III) Test Report(U) (Ft. Hood: MASSTER, 1971), 2,3,26.

[28] LaBay, 19.

[29] Surgent, History and Developed Technology, D-1 to D-8.

[30] Ibid., D-8.

[31] Surgent, M-FOPEN in Hawaii, 22.

[32] "Fundamentals of Networks," Reference Data for Radio Engineers, 5th ed. (New York: Howard W. Sams & Co., Inc., 1974), 6-9 to 6-10.

CHAPTER III

COMPARATIVE ANALYSIS AND EVALUATION

This chapter addresses both radar systems from two different points of view. Part One defines the rating procedures and conditions of comparison. Part Two considers the operational characteristics of each system from a strictly technological or machine point of view. It investigates the optimized machine capability of each system under stated evaluative conditions to perform the combat surveillance and target acquisition mission. In this part, it is assumed that both devices are operating at their design level of efficiency and that operators are fully qualified.[1] Part Three deals with the man-machine equation, or more properly, how does the operator interact with the machine and the external environment of the search area to effectively accomplish the surveillance mission. It investigates operator use of a set and its outputs to achieve target acquisition and identification. It also surveys the related aspects of training, maintenance, and human factors. Part Four summarizes the results of Parts Two and Three.

PART ONE - COMPARISON METHODOLOGY

RATING PROCEDURE

The rating scheme considers individual parameters of evaluation for each aspect addressed in Parts Two and

Three. Each aspect considered will receive an adjectival and numerical rating.

The adjectival rating is derived from a comparative analysis of each system to fulfill an established measure of effectiveness (MOE) or performance criterion. From this analysis, a determination is made specifying which system exhibits the superior capability to perform the stated function and a rating awarded. Ratings are as follows:

3X - one system is superior to the other in all aspects of consideration.

2X - one system is superior to the other in most aspects of consideration.

X - one system is marginally but demonstratably superior to the other.

EVEN - both systems perform equally well.

Adjectival ratings are translated into numerical ratings in the following manner. Each parameter in Parts Two and Three is allotted a maximum number of possible points according to the author's perception of its relative overall importance. The derived adjectival rating acts as a divisor to obtain a numerical rating. For example, a three X rating receives the full possible point value while a two X rating is awarded two-thirds of the possible points. No points are awarded for "EVEN" ratings.

Operational parameters receive the vast majority (75 percent) of points allocated. Also within each category,

parameters are prioritized by point allocation to reflect their perceived relative importance. The rating matrix showing parameters considered and the total number of possible points allocated to each is presented in Table 3-1.

CONDITIONS OF COMPARISON

It is intended that each system be compared under exactly the same conditions as much as possible. Therefore the following stipulations are made for Part Two. Both systems are colocated and positioned such that the antennas of each are deployed at approximately the same height. Possible mutual interference is disregarded. This is predicated to achieve a commonality of clutter and target presentation. Under these circumstances both systems simultaneously search the same area, looking at essentially the same presentation of ground, foliage, and man-made clutter. It insures that each target investigated presents the same cross-sectional area, radial velocity, and duration of movement to each system simultaneously.

REEVALUATION

The author acknowledges the limitations of this study and realizes the reader may disagree with specific parts of the evaluation. In this instance, the reader is encouraged to establish his own performance criterion and point allocation, reevaluate the disputed aspect(s) in terms of his own

Table 3-1. Rating Matrix.

OPERATIONAL CHARACTERISTICS		SYSTEMS CHARACTERISTICS	
PARAMETER	POSSIBLE POINTS	PARAMETER	POSSIBLE POINTS
Acquisition capability in open areas.	15	False alarm rate.	8
Acquisition capability in foliated areas.	35	Target identification.	6
Acquisition capability in built-up areas.	20	Human factors.	5
Radio frequency interference.	5	Training.	3
		Maintenance.	3
SUB-TOTAL	75	SUB-TOTAL	25
TOTAL EVALUATIVE POINTS: 100			

values, and derive his own rating for the issues in question.

AUTHOR'S CREDENTIALS

The author's experience in this field was gained while serving as Operations Officer-Radar at Project Modern Army Special Systems Test, Evaluation, and Review (MASSTER), Fort Hood, Texas from March 1970 to October 1973. Principal duties included the detailed planning, execution, and reporting on nine tests of both systems conducted by MASSTER to determine their military potential to the U.S. Army. The author also served as the Department of the Army Test Representative at six radar tests conducted by other U.S. Army or U.S. Air Force test agencies.

PART TWO - OPERATIONAL CAPABILITIES

GENERAL

The capability of a ground surveillance radar system to detect targets of military interest is dependent upon three variants: the machine, the man, and the environmental condition of the search area. This last variable is rarely in an idealized state that maximizes man and machine performance. Therefore, as a prelude to the operational analysis, the baseline detection capabilities of each system as well as the effects of terrain, foliage, and weather are defined.

DETECTION

Detection is the essential starting point of any target acquisition process. Without detection the operator is unaware of the enemy's presence and the subsequent threat it poses. U.S. Army test agencies have conducted numerous structured field evaluations of both high and low frequency systems specifically designed to determine their detection capability. These evaluations were conducted under actual combat conditions or in a test environment where doctrinally sound stylized offensive and defensive tactical scenarios were used. The ground and foliage conditions were specifically chosen to represent postulated low and mid-intensity threat areas in which the Army could reasonably be expected to fight.

HIFR systems demonstrated a low overall capability to detect targets during these evaluations.[2] They did not give the commander the surveillance capability he desired or expected and thus ranked low on his list of preferred collection assets.[3] HIFR systems were found to be for the most part cued to a target's presence by another surveillance device with a significantly shorter detection range.[4] Under normal circumstances one would reasonably assume that the radar with its longer ranging capability would act as the cueing device. This deficiency was attributed to the radar team's inability to cover its assigned search area.[5] The real problem however lies with the set itself and its limitations of narrow beamwidth, slow scan rate, and LOS requirement for detection.

LOS limitations are addressed in "FOLIAGE" below.

Narrow beamwidth is essentially a problem of design geometry. Given a nominal beamwidth of one to two degrees, the HIFR can only effectively cover three to six percent of a standard 60 degree search sector at any one time (Figure 3-1). This in conjunction with the slow, mechanical scan rate results in the beam being pointed in another direction for a large majority of the time a target is positioned in an area where it is subject to detection.[6] Ideally the radar beam would be positioned in such a manner that it would detect the target as soon as it is exposed. This rarely occurs, however, because the vast majority of posulated threat areas contain at least some form of intervening clutter limiting LOS (Figure 3-2). Therefore a more typical HIFR search pattern is one where the target is not detected until it has traveled some distance away from a mask. The HIFR system is also apt to false alarm or miss a target when its beam crosses the boundry between two distinct clutter environments such as from an open to foliated area.[7] A more detailed discussion of false alarms is presented in Part Three.

LOFR systems on the other hand have demonstrated a 90 plus percent target detection rate in structured field evaluations conducted in all varieties of foliage.[8] When tested in conjunction with other STANO devices possessing a greater ranging capability, it was the initial detector of targets three out of four times and acted as a cueing device

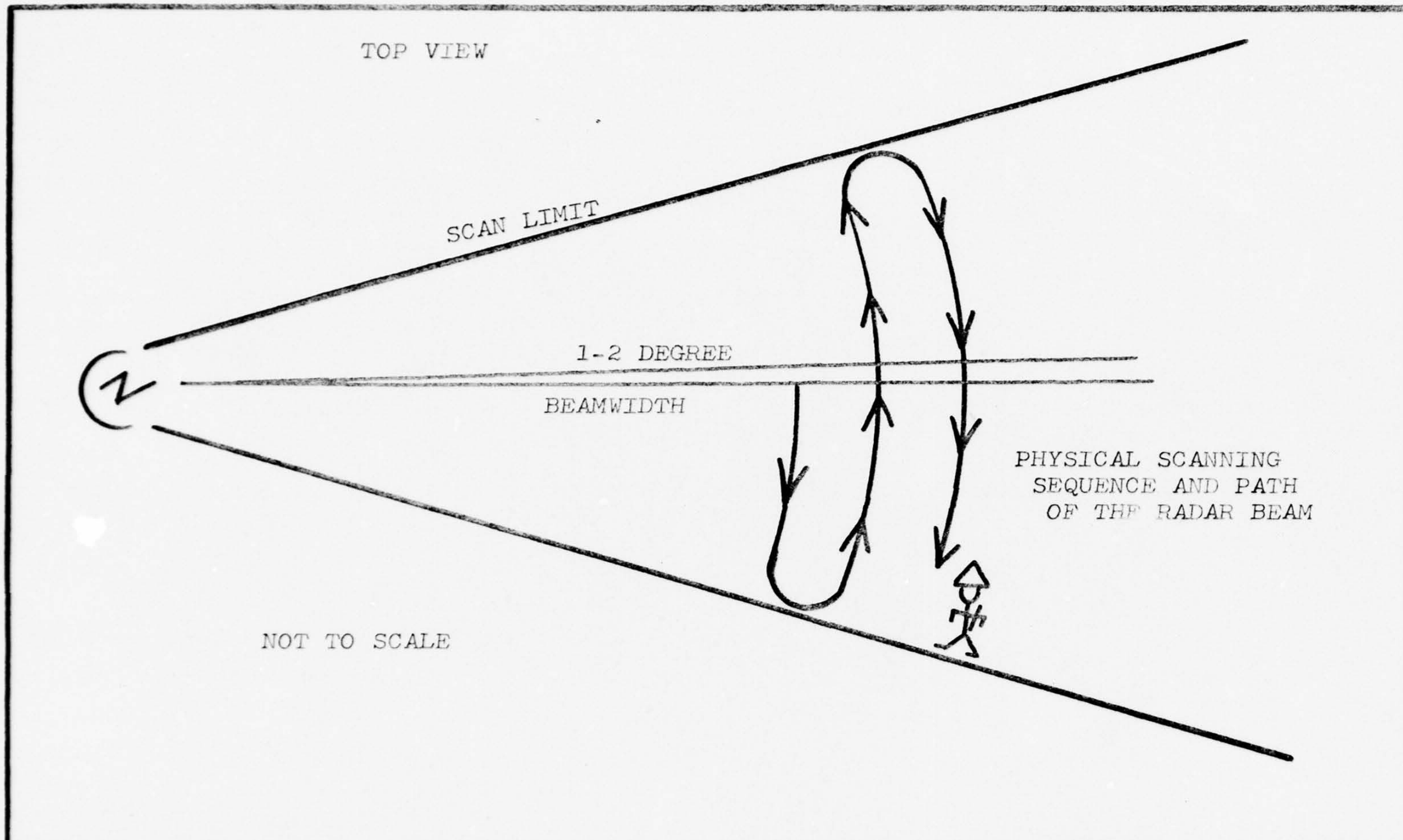


Figure 3-1. HIFR Search Pattern.

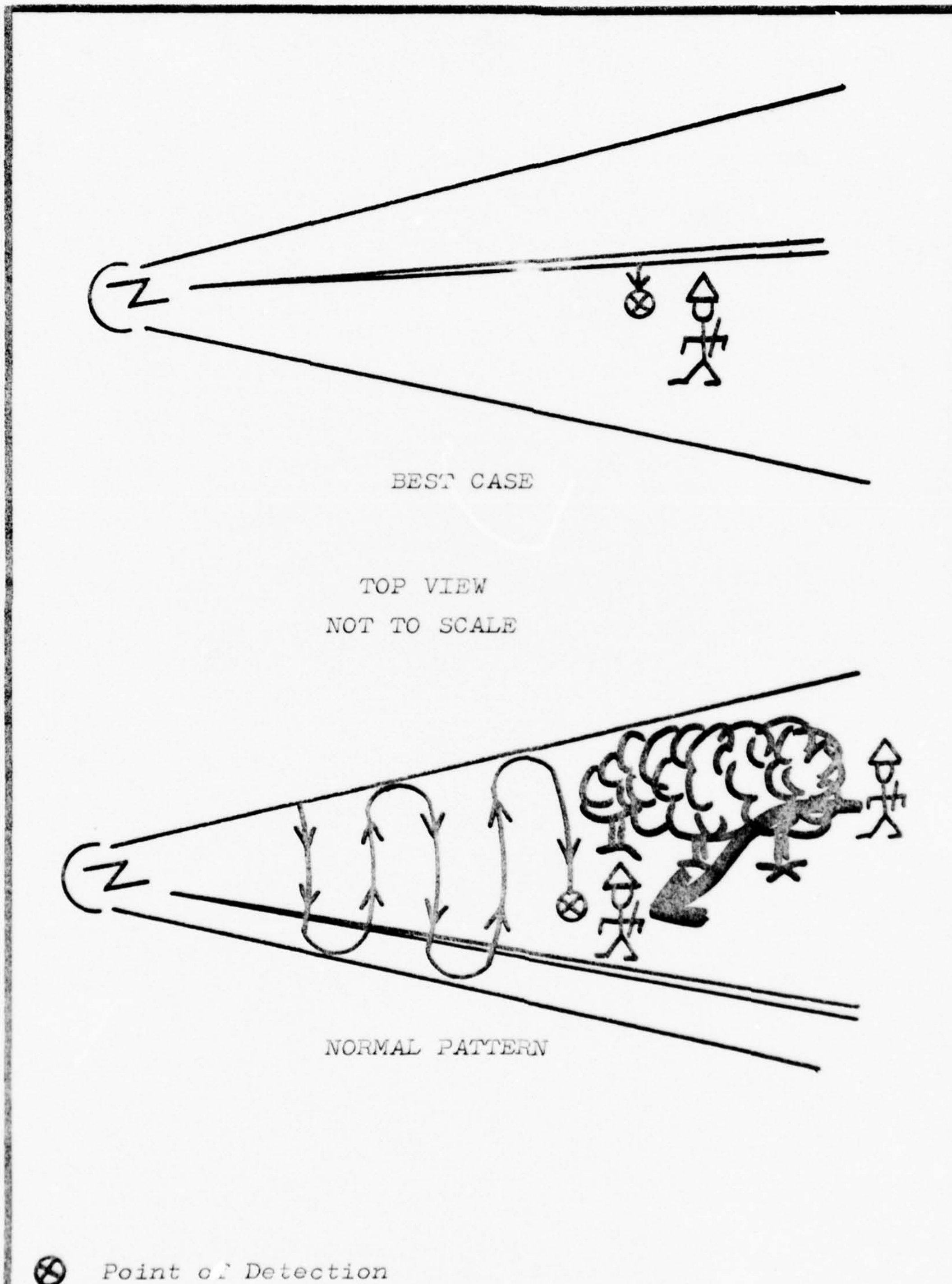


Figure 3-2. HIFR Detection Pattern.

for the other systems.[9] The LOFR sets invariably reported the correct direction of target motion.[10] In the case of two targets simultaneously traveling through the same area, but separated by a considerable distance, LOFR operators demonstrated the ability to detect, locate, and track both with little difficulty in a short period of time.[11]

The reason for this high detection rate is the combination of electronic advancements which permit the set to "see" more of the target area.[12] LOFR electronic circuitry adjusts more quickly and with greater accuracy to the external environment. The balanced doppler signal processing method coupled with the foliage penetration capability permit the set to find and discriminate between the target and the foliated environment even when that target is immersed in foliage. Finally, the almost continuous surveillance of areas within the deployed range gates provides a much higher data rate on a prospective target than the slower mechanical scan/data rate of the HIFR system. Targets are usually detected very soon after they enter the gate often providing the operator sufficient time to process it during the initial detection sequence.[13] LOFR sensitivity is also enhanced because the continuous search of an area without antenna movement eliminates the inherent scan modulation of clutter return associated with radar antennas which physically move in their search mode.[14]

TERRAIN

Neither system is capable of penetrating a solid ground mask to detect targets.[15] Therefore, each must be suitably positioned to minimize ground masking and maximize the amount of usable search area.

FOLIAGE

The HIFR system treats foliage in much the same manner as ground terrain. Static foliage formations such as a clump of trees produce the same visual and aural outputs as ground clutter. There are two other factors which must be considered when discussing HIFR interaction with foliage.

The first is foliage movement. Foliage is rarely at rest but is usually driven in some degree by the prevailing breeze or wind. Wind induced foliage movement within the search beam degrades set sensitivity and subsequently its ability to detect targets.[16] As this movement increases, the set's sensitivity decreases to a point where the set is no longer capable of distinguishing between a target and the foliage. In moderately foliated areas, consisting of large bushes and trees liberally interspersed throughout an open area, this point of nondetection is reached at windspeeds of 10 to 15 knots at the juxtaposition of target and moving foliage.[17]

The second factor is the detection of targets positioned in close proximity to the foliage clutter (Figure 3-3). These targets are often lost or not detected

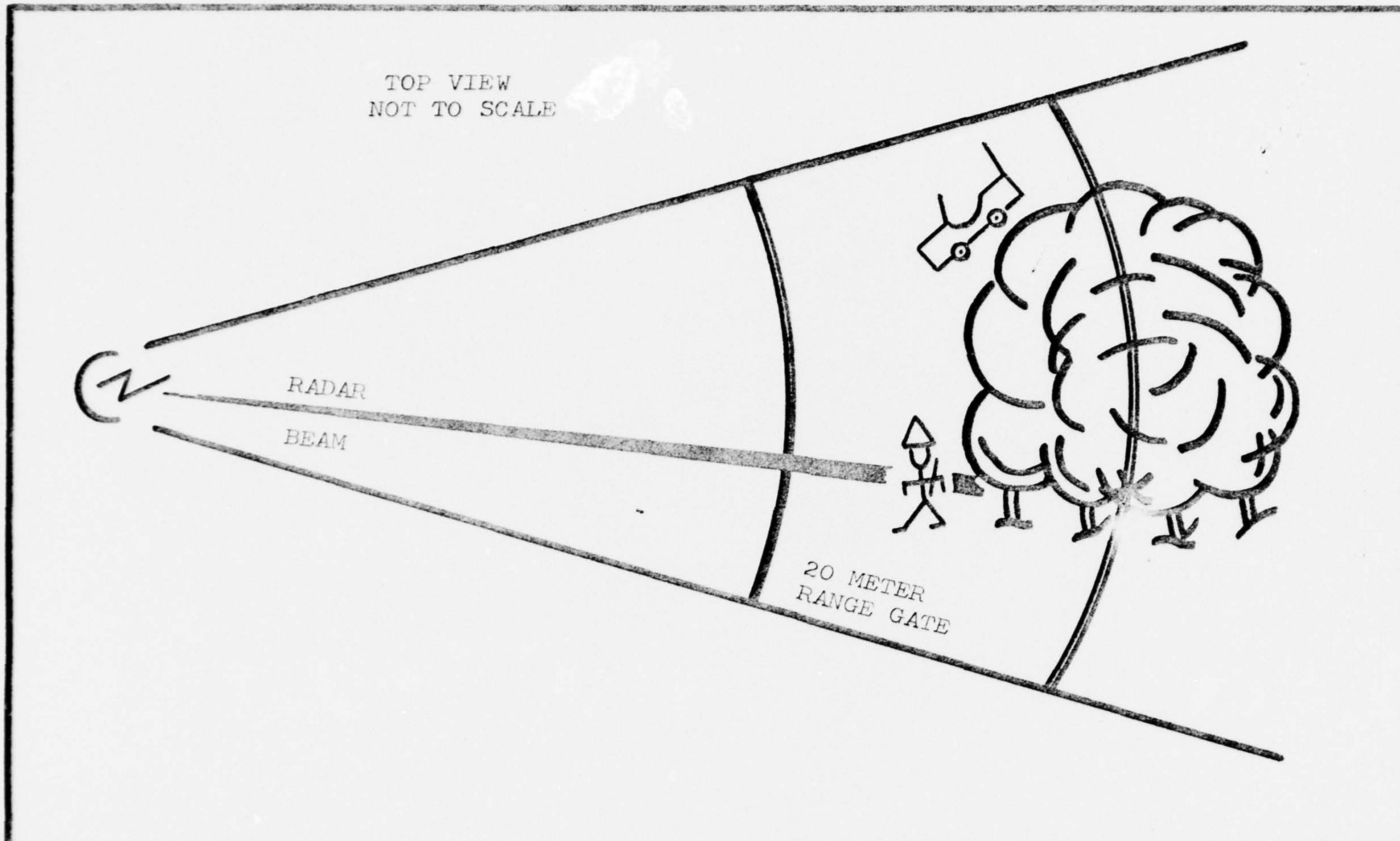


Figure 3-3. HIFR Target Detection at the Foliage Fringe.

because the reflected signal strength from the relatively small moving target within the radar's range gate is obscured by the relatively large foliage clutter return. This situation happens frequently because tactical movement doctrine dictates maximum use of terrain and foliage concealment to mask movement.[18] Under these circumstances, the operator may be able to see the target with his unaided eyes, but not detect it on his radar set.[19]

Briefly summarized, achieved HIFR detection ranges approximate the visual LOS to the target as limited by the intervening ground and foliage masks.[20]

LOFR systems are capable of penetrating the full range of foliage presentations within the electronic design and power limitations of the system.[21] In detecting targets immersed in foliage, the LOFR beam does not directly penetrate through the foliage mask.[22] It uses the area on top of the foliage, the air and the leaves on top of the trees, as a dialectic boundary. The transmitted wave is propagated over and along the tree tops, is scattered down into the foliage and subsequently reflected back to the radar receiver. LOFR's experience no detection problems in the crossover areas and have demonstrated a capability to successfully find targets immersed in moving foliage driven by 25 knot winds.[23] Under these wind conditions, the ranging accuracy remained good, but the bearing accuracy was severely degraded. Above 25 knots the foliage movement changes from a symmetrical to a

non-symmetrical movement mode. At this point, the LOFR is unable to detect targets because the balanced processing function of the radar is unable to cope with fast changing external environment.

WEATHER

In addition to the above constraint, wind per se has an adverse effect on both systems. Wind induced radar antenna oscillation introduces unwanted noise and mirror returns into the radar receiver, degrading set efficiency.[24] This effect is more pronounced at much lower speeds in the HIFR system. LOFR systems demonstrated a surprising capability to operate in winds of 10 to 15 knots with neglible effect on its acquisition potential.[25] Under these conditions, HIFR capabilities were significantly degraded to the point where they are ineffective.[26] As the wind speeds increase, degradation is induced in LOFR systems because of the translational/oscillational motion of its antenna and the increased foliage movement. During this period range determinations remain accurate (±5 meters) but the azimuthal resolution degrades proportionally as the wind increases.[27] Above 25 to 30 knots, LOFR systems are generally ineffective.[28]

Precipitation such as heavy rain and snow also desensitize each system and eventually render them ineffective.[29] However, the LOFR system demonstrated a better operational capability over its HIFR counterpart at lower

precipitation levels, detecting targets when the HIFR system could not.[30]

OPEN TERRAIN

Evaluative Condition

In this parameter, the topography of the evaluation sites vary from barren, level terrain found in the open desert or tundra to open, rolling terrain interspersed with cultivated fields or low foliage formations found extensively throughout the temperate and sub-tropic zones.

Measure of Effectiveness

The capacity of a system to detect and locate targets of military interest traversing over relatively open, flat terrain.

Discussion

Both systems are equally capable of detecting targets out to their design range in flat, open terrain without difficulty.

The HIFR system demonstrates a slight advantage over its LOFR counterpart on rolling terrain. This advantage accrues from the basic difference in high and low frequency wave propagation (Figure 3-4). Simplistically considered, the high frequency wave is propagated in straight lines whereas the low frequency wave bends with a concave propagation characteristic toward the ground.[31] In examining the

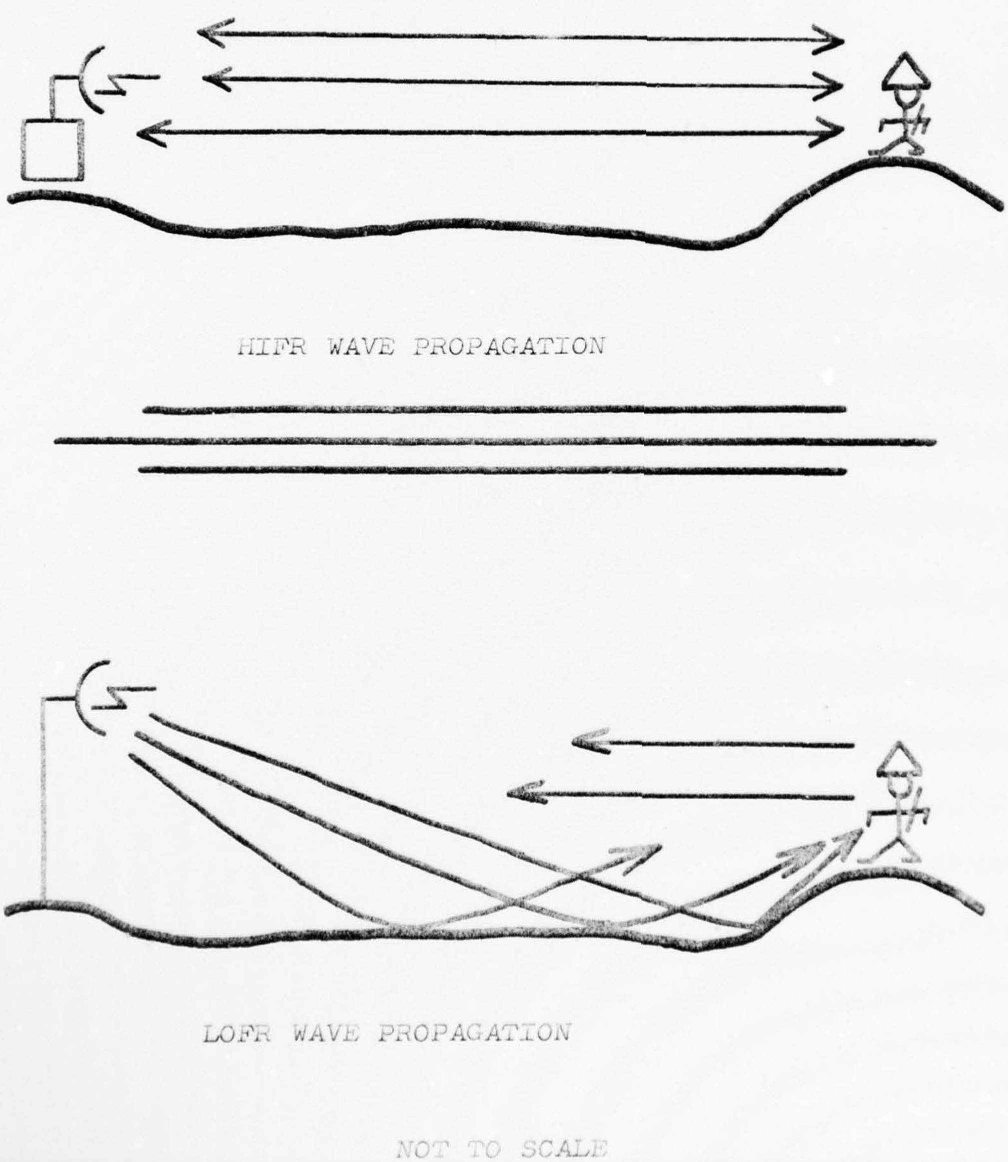


Figure 3-4. Radar Wave Propagation.

target scenario presented in Figure 3-5, neither set is capable of detecting a target at position 1 behind the ground mask. The HIFR would detect the target first as it reached and passed position 2. At position 3 both sets are capable of detecting the target without difficulty. This difference in range of detection (ROD) may vary up to 100 meters depending upon the undulation of the terrain.[32]

In the open, rolling terrain with cultivated areas, the LOFR demonstrates a marked advantage over the HIFR system.[33] The height of the intermittent foliage formations or cultivated areas may obscure enough of the target's cross-sectional area (positions 4 and 5) to preclude detection by the HIFR. This would be especially true in the summer months when foliage is high and full. In this circumstance the radar operator may be able to see the target with his unaided eyes but not detect it on his set.[34] Wind driven movement of these grain fields or bushes would further degrade the HIFR's capability to detect the target. The LOFR would experience no difficulty in detecting targets at positions 4 and 5 unless the wind was very severe.

In this flat, bare ground environment, the shorter range LOFR is much more susceptible to enemy observation because of its characteristically high antenna mast.[35] Antenna heights of 30 to 50 feet are now required to increase the LOFR's range and provide the system with adequate signal coverage on the ground at maximum design range (Figure 3-4). This presents a tactical problem to using units in that their

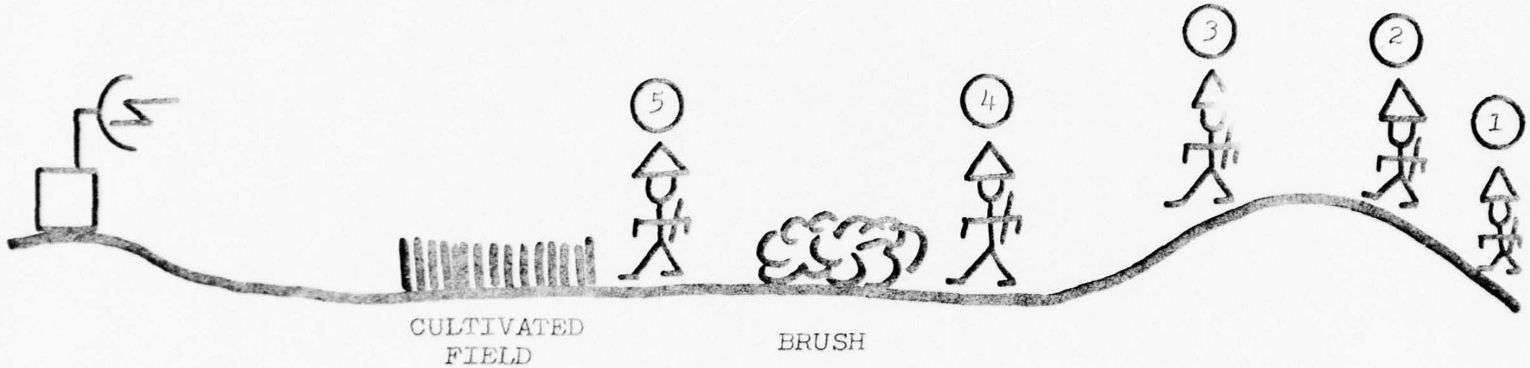


Figure 3-5. Target Scenario For Open Terrain.

positions are easily compromised and subject to the neutralizing effects of enemy fires, jamming, or avoidance. This situation is generally applicable only to open areas where LOS is not a limiting factor. In foliated or built-up areas this vulnerability decreases significantly because the antenna and mast are much more easily concealed or obscured from enemy ground observation.

Both systems are vulnerable to detection by enemy electronic direction finding (DF) devices because of the high power level and distinctive, discrete manner in which they transmit. This is a common deficiency of all active emitter radars and applies equally in any terrain environment. It must be noted however that the HIFR is more vulnerable to detection because it is currently the sole user of its frequency band. LOFR's operate at frequencies close to those used by the Soviet and United States field forces for tactical communications.[36]

Summary

The LOFR system exhibits a marginal acquisition superiority over its HIFR counterpart to find partially obscured targets. It is felt, however, that this is counterbalanced by its tactical susceptibility to enemy observation and possible neutralization or avoidance. Both systems are equally vulnerable to electronic detection provided the enemy properly identifies the operating frequency and electronic characteristics of each system.

In this parameter both systems are judged to perform equally well. Therefore an even rating is awarded with no points given to either system.

FOLIATED TERRAIN

Evaluative Condition

The topography of this evaluation site is depicted in Figure 3-6. The ground rises slightly from the radar set to the saddle in the east such there is intervisibility between the set and the road through the saddle over the intervening trees. The time is early summer and the foliage is at its median growth point. All hills depicted are covered with small trees and brush. Each set is positioned to permit maximum coverage of the assigned area. The topography, foliage, and intervisibility (1500 to 1800 meters) are representative of the terrain found extensively throughout Western Europe, especially rural West Germany.

Measure of Effectiveness

The capacity of a system to detect and locate targets of military interest traversing over foliated terrain.

Discussion

Each system's capability to detect and locate targets of military interest in this foliated environment varies a great deal.

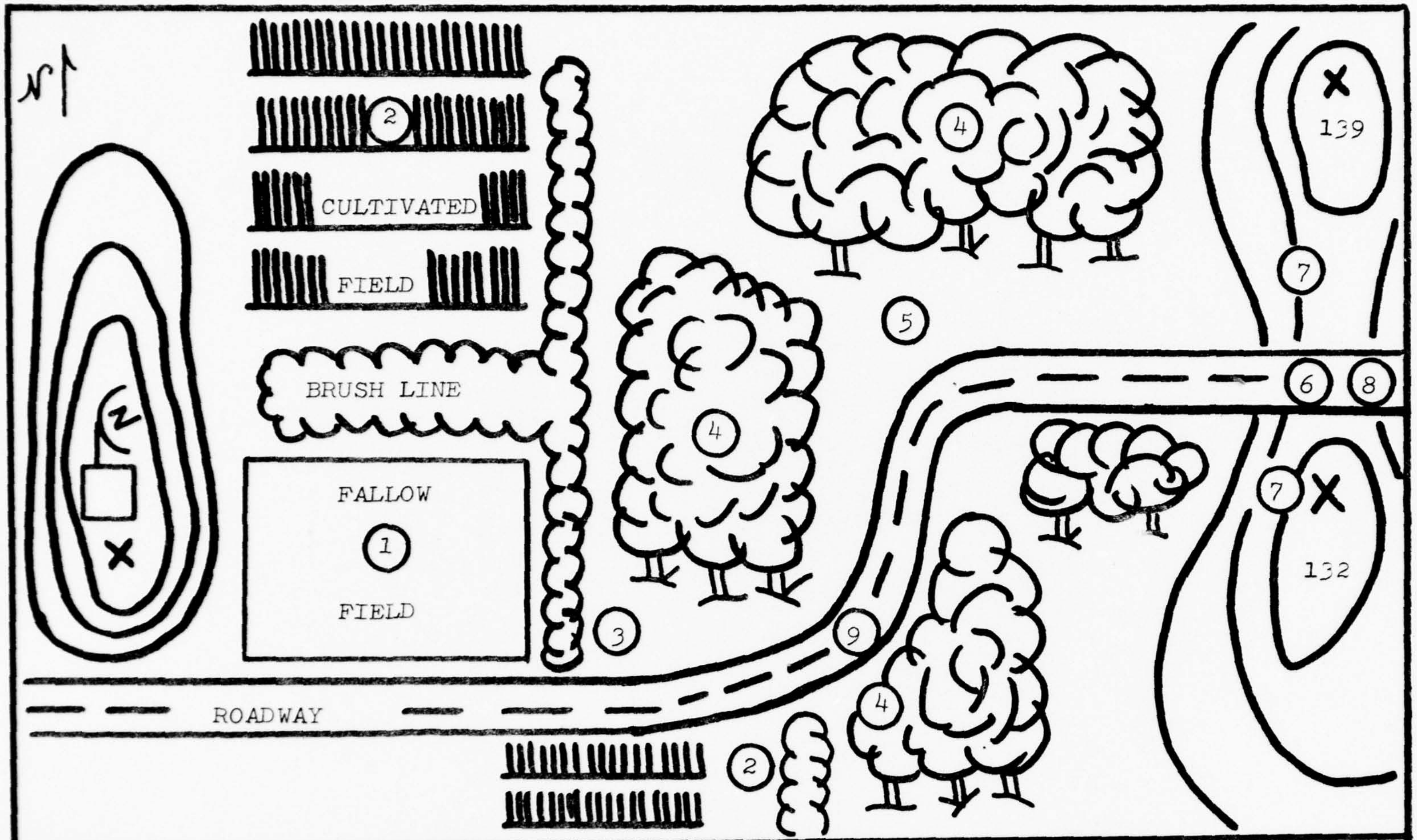


Figure 3-6. Target Scenario for Foliated Terrain.

The HIFR system is capable of easily detecting targets located at positions 1, 6, and 9 because of unobstructed LOS to these locations. Conversely, the HIFR is not capable of detecting any targets at positions 4, 5, 7, and 8 because of the absence of LOS. Positions 4 and 7 are immersed in foliage and position 8 is situated behind a ground mask. Although position 5 is located in an open area, the radar's LOS is blocked by the intervening stand of trees. HIFR effectiveness against targets located at positions 2 and 3 is questionable. The height and density of the mask obscures a portion of the target's cross-sectional area, making detection of this now smaller target more difficult. This situation can be further aggravated by wind induced foliage movement. Under average conditions it is estimated that a HIFR system would detect 50 percent of these targets.

The LOFR system is capable of detecting and locating all targets without difficulty except those at positions 8 behind the ground mask. It is noted that the HIFR has the first opportunity of detecting a target approaching position 6 because of the LOFR's ground wave propagation characteristics.

Figure 3-7 presents a composite diagram of each system's capability to detect and locate targets in this scenario. It graphically demonstrates that use of a LOFR permits the commander to "see" a much larger portion and more critical terrain features of the battlefield at any one point in time. Needless to say, operation in a densely foliated jungle area

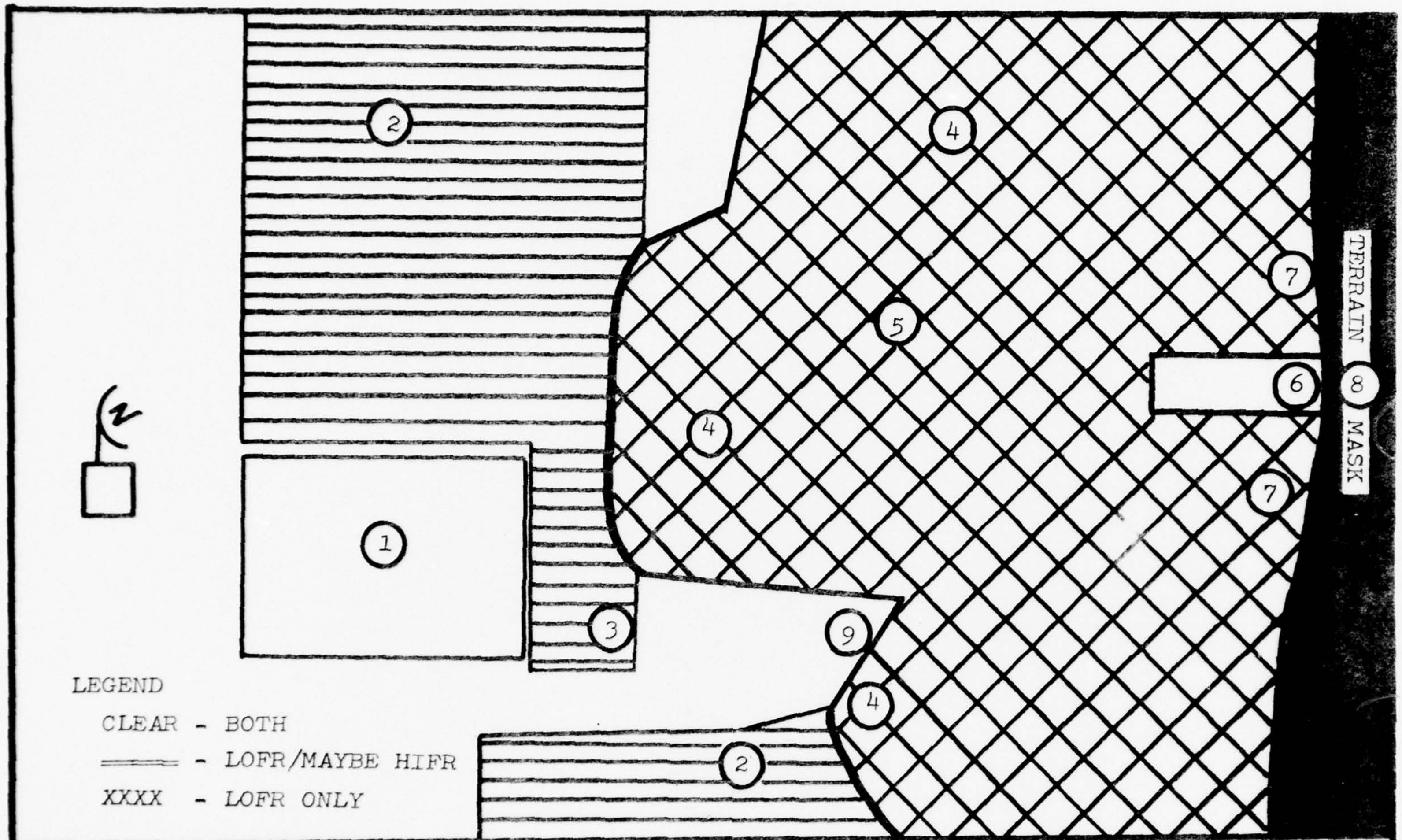


Figure 3-7. Composite Capability Diagram for Foliated Terrain.

would further limit each system's capability with a greater adverse impact experienced by the LOS dependent HIFR.

Summary

As shown in Figure 3-7, the LOFR system exhibits an overwhelming superiority over its HIFR counterpart in foliated terrain. The capability of the LOFR system to detect targets located in or near the foliage fringe gives the commander a preemptive opportunity to engage an enemy before the enemy can employ his direct fire weapons systems. This is a significant tactical advantage.

For this parameter, the LOFR system is awarded a 3X rating valued at 35 points.

BUILT-UP AREAS

General

According to Soviet doctrine, "Military operations in built-up areas [MOBA] are an integral part of combat operations and present special opportunities and challenges to commanders at all levels."[37] Until recently, the US military establishment has paid lip service to developing the doctrine and tactics to conduct MOBA.[38] Renewed interest in this topic has been generated by increased Warsaw Pact emphasis on and training in MOBA.[39] Based on their hard earned experience in World War II, the Soviets have long recognized the importance of MOBA and are allocating increasing amounts of training resources and time to perfect MOBA tactics and

doctrine.[40] The Soviet point of view was published in 1971 by Major General A. K. Skovkolovick of the Soviet Army, writing in *Combat Operations of the Mechanized Rifle Battalion in the City*. MOBA requires an offensive spirit and a force with the requisite boldness, fortitude, and resourcefulness to be victorious in the cities.[41] At present there is no DA proponent agency solely tasked with updating our combat-in-cities (CIC) doctrine although several ongoing studies are being conducted, including a joint effort by TRADOC with the Federal Republic of Germany.[42] Existing U.S. doctrine essentially says "stay out of town; it is a very nasty place to fight."[43] We can reasonably expect in Europe, especially in West Germany, the most urbanized area in the world, that the Soviet Union will use built-up areas (BUA) if they attack.[44] This assumption is based upon the Soviet "hugging" technique to minimize the effects of NATO nuclear strikes, the size and frontages of their combat formations, and their postulated use of the main road networks through cities and towns.[45] Again, knowledge of the enemy's strength and dispositions becomes a matter of prime importance to the commander. At present our surveillance capability in BUA is largely limited to troop reconnaissance, a hit and miss tactic which can become costly in men and material.[46] LOFR technology offers the commander another option and a new method of finding the enemy in urbanized areas.

Evaluative Condition

The evaluative test site depicted in Figure 3-8 represents a low level of urbanization. This is considered the least restrictive case as there are numerous open spaces interspersed throughout the suburban complex. The area consists of stone or wood houses of two stories or less, intersecting streets, and high voltage or feeder power lines crisscrossing throughout.

Measure of Effectiveness

The capability of a system to detect and locate targets of military interest in a built-up area.

Discussion

A HIFR located at any place other than position 2 would contribute nothing to the commander's surveillance effort because of LOS constraints. Even at position 2, its value is neglible because the search area is restricted to the street out to its LOS capability. Its vulnerability to enemy detection and neutralization in this position is very high because of the relatively short ranges involved. For these reasons, HIFR plays a neglible role if any in MOBA.[47]

LOFR technology on the other hand has demonstrated a capability to detect, locate, and track targets in an uncontrolled BUA.[48] To make these detections the LOFR penetrated a number of natural and man-made obstacles such as trees and houses. It also operated directly under power feeder

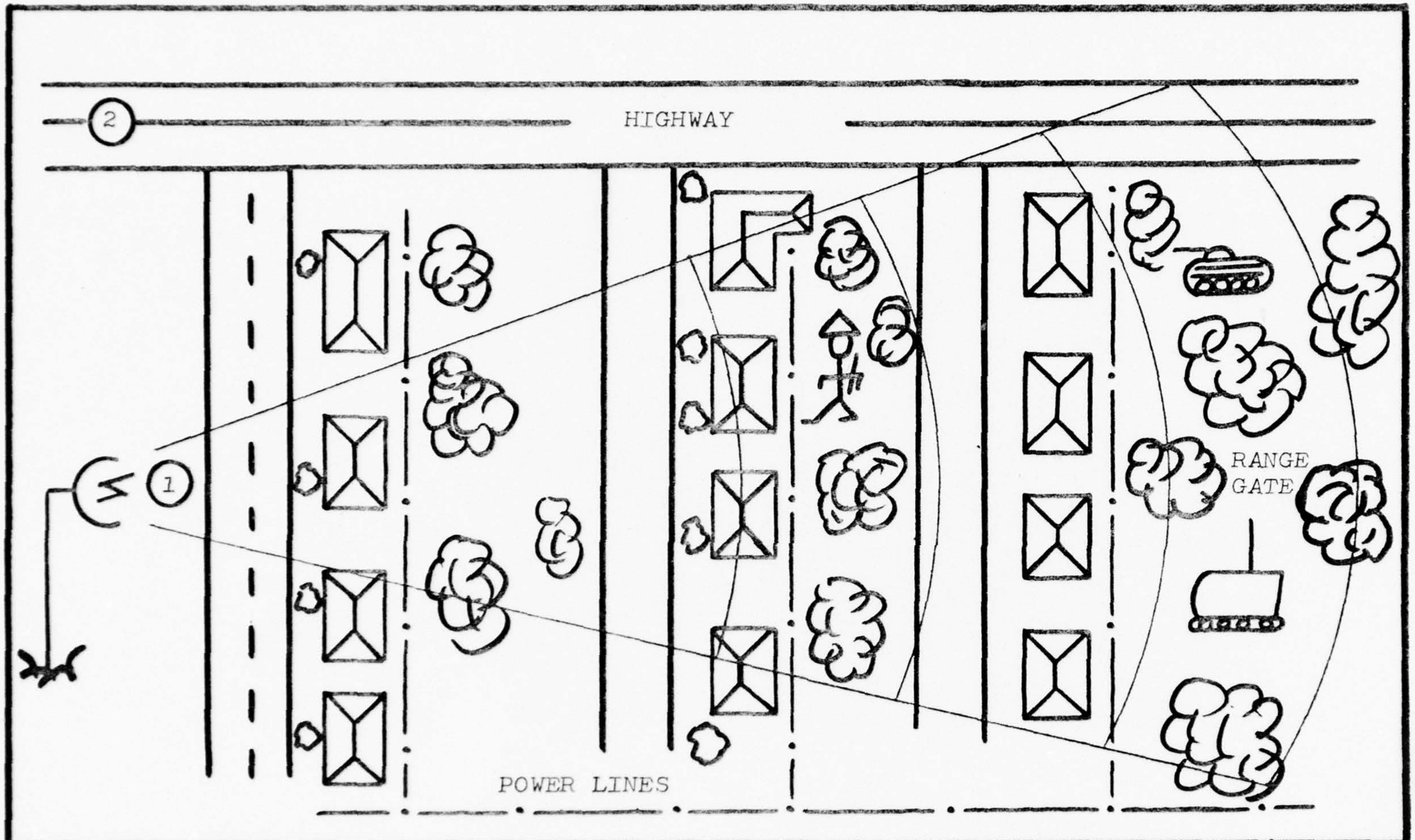


Figure 3-8. Target Scenario for Built-Up Areas.

lines and close to high voltage transmission lines with negligible degradation. Using a map of the area, operators were able to distinguish between test targets and other uncontrolled, spurious targets in the area. They were also able to discern activity within specific houses.[49] This represents a quantum jump of some magnitude in improving the commander's surveillance capability in BUA, a capability which to now has been limited to physical reconnaissance of an area, in effect a house-to-house, visual inspection. Research has found no other test of this application. Therefore, without any additional test or theoretical data available, no valid extrapolation of the LOFR's capability under more restrictive conditions can be made.

Summary

LOFR technology represents a quantum jump in the commander's ability to "see the battlefield" in BUA. It permits previously impossible surveillance of enemy held or unoccupied neutral territory without endangering lives. While the system cannot discriminate between friend and foe, it does identify areas of activity and therefore potential threats. It permits the commander to better exploit his limited manpower resources and to exercise flexible economy of force tactics in these areas.

For this parameter, the LOFR system is awarded a 3X rating valued at 20 points.

RADIO FREQUENCY INTERFERENCE

Evaluative Condition

Both sets are colocated in a forward area with each equally subject to interference from the large number of active emitters normally found in the heightened electromagnetic environment of combat. This condition discounts mutual interference between sets and does not include electronic countermeasures such as jamming, which are specifically designed to degrade or negate radar effectiveness.[50]

Measure of Effectiveness

The capability of a system to operate at its design potential in the heightened electromagnetic environment of combat without suffering operational degradation caused by radio frequency interference (RFI).

Discussion

With the exception of the AN/PPS-9, HIFR systems show a marked vulnerability to induced RFI from other active emitters. Standard U.S. tactical FM radios operating within 50 meters of an AN/PPS-5A radar set will disrupt its receiver sufficiently to prevent any target detection by the set unless the radio is properly shielded.[52] The AN/PPS-5A is also vulnerable to interference from distant (5-10 kilometers) high power emitters.[53] This presents the radar team with a tactical communications problem for they must displace their primary means of communication away from their operating site.

This problem is further compounded if no remoting capability is available and target information must be relayed by voice to a radio-telephone operator.

Conversely LOFR systems exhibit a low vulnerability to RFI. Their advanced internal circuitry is better able to respond to, filter out, and cancel spurious external signals than the HIFR systems.[54] Standard FM and multichannel radios operating at full power next to the LOFR antenna have no noticeable effect on the radar.[55] The constant keying of these FM radios did not disrupt or affect radar operation.[56] In the event interference does occur, the operator is able to discern, measure, and determine a gross bearing to an offending RFI source by using his visual outputs. Knowing this he can take appropriate steps to work through the interference or realign his antenna to reduce it.[57]

LOFR radar testing in built-up or residential areas has also shown that the system can operate in close proximity to high tension and feeder power lines with neglible side effects.[58]

Summary

The LOFR system demonstrates an overwhelming superiority over its HIFR counterpart to operate effectively in a RFI rich environment. For this parameter the LOFR is awarded a 3X rating valued at 5 points.

OPERATIONAL CAPABILITIES SUMMARY

In this category, the LOFR is found to equal or outperform its HIFR counterpart in all parameters of comparison. This machine superiority is directly attributable to four distinct factors: advanced internal design, a high scan rate, the capability to master its environment, and finally the unique capability to penetrate foliage. The potential demonstrated by fielded implementations of LOFR technology offer the commander a significant increase in his ability to "see the battlefield" in any environment. A summary of the above results is presented in Table 3-2.

Table 3-2. Results of the Operational Capabilities Comparison and Evaluation.

		RATINGS AWARDED		POINTS AWARDED	
	POSSIBLE POINTS				
PARAMETER		HIFR	LOFR	HIFR	LOFR
Acquisition Capability in:					
Open Terrain	15	EVEN	EVEN	0	0
Foliated Terrain	35	--	3X	0	35
Built-Up Areas	20	--	3X	0	20
Radio Frequency Interference	5	--	3X	0	5
TOTAL	75	--	2X	0	60

PART THREE - SYSTEM CHARACTERISTICS

GENERAL

Whereas the last section dealt only with the machine, this section investigates the interaction of man and machine. It looks at how well an operator is able to use fielded implementations of each radar technology to accomplish the surveillance mission. Five operator dependent parameters are examined. They are false alarm rate, target identification, human factors, training, and maintenance. False alarms are addressed here rather than in the operational section because it is the operator who determines whether a set's target indication is true or false. This concept leads to a more general conclusion about ground surveillance radar operations: the man, not the machine, is the key to success. He is the final determinant in any situation, with the machine acting only as an aid or means to assist him in achieving that end.

FALSE ALARM RATE

Measure of Effectiveness

The demonstrated ability of an operator to discriminate between a false target and a true target of military interest.[59]

Discussion

False alarms are usually generated in a ground surveillance radar set by two basic causes: fundamental set design and the external environment. In the first instance,

false alarms occur when the set, attempting to reduce noise (or false alarm probability), cannot suitably adjust quick enough to cope with the external environment.[60] In the second instance, false alarms may also be generated internally within the set itself or operationally when the radar beam crosses the boundry between two distinct clutter environments, i.e., foliated to open terrain.[61] The solution to this noise and clutter problem is a procedure for "selecting sets of filter coefficients by classifying the autocorrelation function of the received clutter so as to realize a prescribed [or predictable] false alarm probability."[62] Therefore, in any particular system, it is necessary to have a method of automatically setting the detection threshold such that the false alarm probability of the radar is maintained at or below a certain value while maximizing the radar's capability to detect targets.[63]

HIFRs experience a relatively high false alarm rate due primarily to the reasons stated above.[64] The radar set's method of suppressing noise while concurrently dealing with the static and moving foliage of the environment is less than desired. In this instance the false target indication generated is a valid sensing on the part of the radar in that it reacted properly in reporting the movement of an object of requisite size and velocity. However, since foliage is not a target of military interest, this particular sensing is classified as a false alarm. This is disconcerting to an

operator because moving foliage produces numerous transient false indications, all of which yield nothing upon investigation.

Field evaluations of LOFR's show them to experience a very low false alarm rate.[65] This is again due primarily to its advanced design which automatically reduces internal receiver noise, optimizes set sensitivity, and surpresses the moving foliage clutter by means of a balanced doppler signal processing method.[66] LOFR operators are able to quickly identify false target indications from their aural and visual readouts which provide a much more refined presentation of the target indication than that found in HIFRs.[67] They are also able to readily distinguish between spurious targets and targets of military interest presented in the test scenario.[68] HIFR operators were not able to do this.

Summary

The LOFR systems exhibit a marked advantage over the HIFR systems in both a lower false alarm rate and their capability to provide the operator with the means to distinguish between spurious and real targets of military interest. Although both are subject to false alarms, LOFR susceptability to them is considerably less because of its "tight" internal design and its capability to better deal with the external environment.

For this parameter the LOFR system is awarded a 3X rating valued at 8 points.

TARGET IDENTIFICATION

Measure of Effectiveness

The ability of an operator using the outputs of his set to correctly determine the type and relative size of the detected target. This MOE presupposed that the target detected is valid and one of military interest.

Discussion

This parameter examines the efficacy of a system's outputs and the relative difficulty an operator experiences in interpreting them properly. Therefore, the better the readout, the more easily and accurately an operator will be able to estimate target type and size.

Operator determined target descriptions derived from HIFR visual and aural outputs have proven to be unsatisfactory.[69] Commanders place little reliance on radar operators to provide them with an accurate target description.[70] Technical improvements and revised training procedures have somewhat alleviated this deficiency but not to an acceptable level. For example, AN/PPS-5A and 9 operators correctly identify only one out of every four targets presented.[71] Data shows that "operators were unable to identify target type correctly at better than chance level . . . [or to] distinguish personnel from vehicular targets reliably. Clearly the inability of operators to identify targets correctly in an operational environment is a serious limitation."[72]

On the other hand, the refined visual and aural presentations of LOFR's are sufficiently distinctive in their nature and intensity to enable operators to identify targets with a high degree of accuracy.[73] Operators are able to distinguish between personnel and vehicular targets as well as accurately estimate their relative size over 90 percent of the time.[74] The output presentations also permitted operators to distinguish between targets of military interest and spurious targets such as livestock and birds.[75]

A practical example points up the essential differences in each system. Assume that the range gate of each system is positioned on exactly the same piece of terrain. As the first man of a five man reconnaissance team enters the gate, each set will yield a visual and aural indication of target presence. Both operators would discern a distinctive change in the doppler audio tone with the HIFR operator receiving a "blip" on his scope and the LOFR operator an increase in his meter. As more elements of the team entered the gate, the HIFR operator would discern an slight intensification of the "blip" and difference in the audio tone until a maximum was achieved when three members of the team were in the gate. Three members are considered the maximum number present in the gate at any one time because it is assumed the team would travel over the terrain with a 5 to 10 meter tactical separation distance between men. As the third team member began to leave the gate, the intensity of the target indications would decrease until the last man exited. The

LOFR operator would be presented with quite a different visual picture although the audio presentation would be approximately the same as the HIFR system. As the first man reached the center of the gate, the meter would peak and then drop off slightly, rising again to a higher peak as the second man approached and reached the center of the gate. This sequence would continue as each member of the team passed through the gate and exited from it. A graphic representation of this targeting sequence highlighting the differences is presented in Figure 3-9. In this sequence, the LOFR operator is able to investigate each target individually, in effect count each one, while the HIFR operator is only presented a gross representation of the entire sequence. This aspect of operation is responsible for the LOFR operator attaining a much higher target identification rate.

Summary

The LOFR system provides the operator with more discriminate changes in target presentation thereby permitting him to identify targets with much more reliability. This difference in identification reliability, 90 percent versus 25 percent for HIFR operators, represents a significant improvement in this area. It further demonstrates the efficiency of the LOFR system's outputs to achieve a better man-machine interface.

For this parameter, the LOFR system is awarded a 3X rating valued at 6 points.

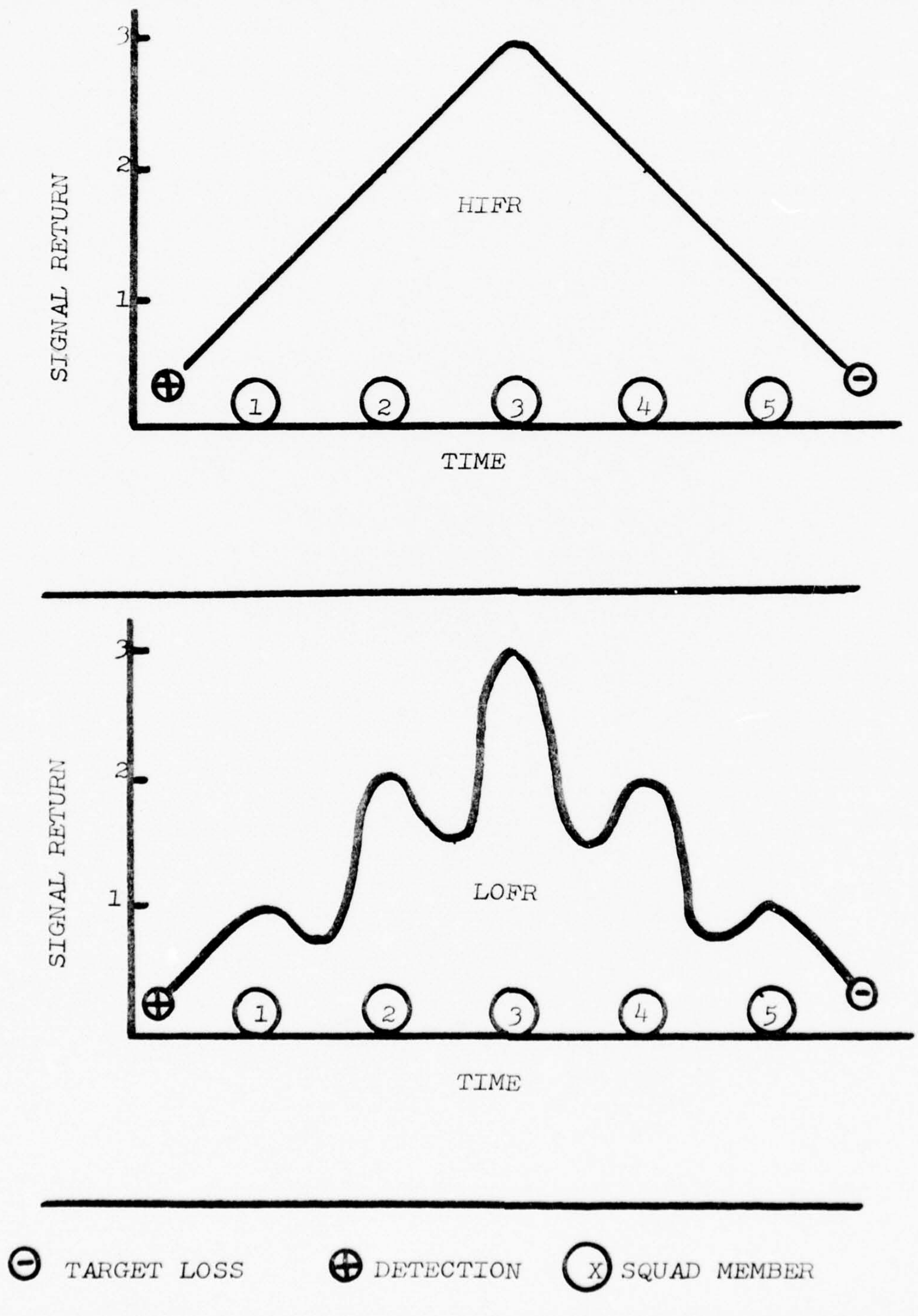


Figure 3-9. Target Progression Through a Range Gate.

HUMAN FACTORS

Measure of Effectiveness

The ease with which the man-machine team accomplishes the ground surveillance mission. This parameter addresses operator fatigue associated with sustained radar operation, operator acceptability of the radar, and operator confidence in a set's performance.

Discussion

HIFR systems to include those with automatic alarms require constant operator attention. The fatigue resulting from this is a significant deficiency common to all HIFR systems. Normally one man can effectively operate a set for an average of 30 to 45 minutes.[76] The maximum time of effective set operation is 60 to 75 minutes, dependent upon the individual operator and the level of activity. Once these limits are reached, operators begin to experience debilitating eye and ear strain, headaches, and backaches.[77] Operator fatigue peaks during low activity periods due to the boredom caused by the constant, monotonous feedbacks of the visual and aural outputs. Along with this fatigue comes a loss of interest in set operation.[78] The resultant diminution of operator efficiency caused by fatigue and loss of interest leads to a growing lack of confidence in the set and the operator himself.[79]

LOFR systems, on the other hand, have been well received by operator personnel. During periods of high activity, operators can effectively function for two hours and more without experiencing any adverse physical effects. This period is extended even more during periods of low activity. The reason for this is the set automatically performs the surveillance function. The operator is free to perform other tasks until the set alerts him to a target's presence.[80] This facet of operation significantly reduces fatigue and expands the length of time a single user can effectively operate the radar.[81] The combination of less fatiguing operation and reduced boredom serves to reinforce operator confidence and maintain his interest in set operations.[82] Soldiers expressed confidence in the systems to perform effectively in combat.[83]

Summary

The human factors aspect of radar operation is maximized in the man-machine equation when using a LOFR system. This is due primarily to the LOFR's heavy reliance on the machine to perform the tedious mechanics of surveillance whereas HIFR systems depend heavily on the operator for this function. The result is that the LOFR is significantly easier to operate and generates much less operator fatigue. It subsequently earns better operator acceptability and confidence in its performance than its HIFR counterpart.

For this parameter, the LOFR system is awarded a 3X rating valued at 5 points.

TRAINING

Measure of Effectiveness

The ease with which a soldier is trained to be a qualified operator of a particular system. This MOE addresses the requisite skills of a candidate operator as well as the formalized training and practical experience required to produce an effective operator.

Discussion

In this parameter the key discriminator is simplicity: simplicity of operation; simplicity in the methodology of finding a target; and simplicity in the means of maintaining peak performance.[84]

With the exception of the AN/PPS-9, formalized school training complimented with extensive field experience are required to produce a proficient HIFR operator.[85] This background is essential to develop the skills required to understand the set's operational characteristics, perform the numerous manipulative adjustments, and provide a strong data base of experience and knowledge upon which the operator will draw when making routine operational decisions and judgments.[86] This dictates the selection of above average soldiers with the requisite mental and motor skills to be HIFR operators and subsequently limits the manpower pool from which candidate HIFR operators (MOS: 17K) can be drawn.[87]

The simplicity of LOFR operation allows the selection of a lower skill level soldier to be an operator and requires less time to train him to operate a set effectively. Personnel with some radar background were easily and adequately trained to operate the most complex LOFR systems in less than two weeks.[88] Because of the LOFR's relatively simple operational procedures, more people with lower skill levels can be trained to operate this type of system. The U.S. Army has fielded a highly reliable, short range, foliage penetration radar detector which required less than one hour of training to transform an average infantryman into a qualified operator.[89] Additionally, personnel who operated the most complex implementation of this technology stated that there appears to be no requirement for special skills in order to become proficient in that particular radar's operation.[90] The commonality of current LOFR technology permits developers to incorporate into any new systems all those advantages of previously fielded implementations.

Summary

The LOFR system exhibits a marked superiority over its HIFR counterpart. Its translation of state-of-the-art technology into a relatively simple acquisition device demonstrates a capability to lower a potential radar operator's skill, aptitude, and the time required to train him as an effective user of the equipment.

For this parameter the LOFR system is awarded a 3X rating valued at 3 points.

MAINTENANCE

Measure of Effectiveness

The ease with which a system can be repaired. In addition to mean time to repair (MTTR) considerations, this MOE also addresses repairman skill levels and the time and effort he must expend isolating radar faults.

Discussion

This is a difficult parameter to evaluate because of the sketchy data available on LOFR systems. Although a strict comparison cannot be legitimately made, the limited data available permits us several valid extrapolations to form a basis of comparison. One may reasonably conclude that the AN/PPS-5A and AN/TPS-58 will continue as the Army's standard medium and long range ground surveillance radars into the foreseeable future. This is predicated on the fact that there is no concerted on-going R&D program in the Army to replace them.[91]

HIFR's tend to be unreliable despite the fact all have enjoyed a relatively normal development cycle and have been in the inventory for several years.[92] Current user availability averages approximately 60 percent, far below the DA desired goal of 90 percent.[93] Too often these radars require direct support level calibration or repair after

being tactically transported or handled roughly in the field.[94] This usually means the set must be evacuated to a repair facility, resulting in the loss of that asset for sizeable periods of time.[95] Another factor which has not yet been adequately assessed is the advancing age of the AN/PPS-5A system, the maneuver commander's main source of radar intelligence data. A large number of these sets, converted from the AN/PPS-5 to the AN/PPS-5A configuration, are now approaching or are over the 10 year age mark. The natural deterioration due to long use, environmental decay, and frequent repair is beginning to place increasing burden on an already saturated maintenance and repair parts supply system. Under these circumstances, the situation can only get worse. Another problem is that few repairs can be accomplished at a tactical site. Repair requires a highly skilled repairman (MOS: 26*), the requisite tools, test equipment, and a suitable "clean" area in which the faulty set can be opened, troubleshooting done, and repair accomplished.[96]

Individual test results of LOFR's systems shows them to possess a high reliability and availability rate (over 95 percent) above normally accepted standards.[97] Tactical transportation and rough field handling during testing did not require the sets to be recalibrated or repaired.[98] Operator maintenance consists mainly in keeping the set exterior clean and external connections serviceable.[99] All sets are provided with a BITE capability to assist operators

in identifying faulty set operation or components. The next level of maintenance consists of using an electronic test set on established test points built into the radar to determine, in detail, the faulty component of the set. This test set is simple to operate and closely resembles the "tube testers" one finds in local drugstores. Since the system is designed on the circuit board concept, the faulty board can be replaced on the spot with a serviceable one taken from the repairman's spare parts load. The set is back in operation in a very short time without having to be disassembled, evacuated to the rear, and subsequently returned to the using unit. This aspect alone greatly increases a LOFR's availability rate. A similar method is currently used to repair tactical FM radios and has proven highly successful in reducing downtime and improving equipment availability.

Summary

The advantages and methods of the LOFR repair are found to be far superior to those associated with HIFR systems. The quick, easy, on-the-spot repairability of the LOFR provides for maximum utilization by the using unit. The simplicity and ease of repair facilitates training prospective repairmen and allows the Army to use a lower skill level soldier to perform this essential function.

For this parameter, the LOFR system is awarded a 3X rating valued at 3 points.

SYSTEM CHARACTERISTICS SUMMARY

In this category the LOFR system outperforms its HIFR counterpart in every parameter of comparison. Its advanced internal design provides more refined outputs to better identify targets. Its improved method of dealing with the environment significantly reduces false alarms. Its simplicity of operation facilitates operator and repairman training, increases the amount of time an individual can operate the set, and reduces the requisite input skill levels of both. Since it can be repaired rather easily on the spot, it most importantly increases system availability to the maneuver commander. A summary of these results is presented in Table 3-3.

Table 3-3. Results of the System Characteristics Comparison and Evaluation.

		RATINGS AWARDED		POINTS AWARDED	
	POSSIBLE POINTS				
PARAMETER		HIFR	LOFR	HIFR	LOFR
False Alarm Rate	8	--	XXX	0	8
Target Identification	6	--	XXX	0	6
Human Factors	5	--	XXX	0	5
Training	3	--	XXX	0	3
Maintenance	3	--	XXX	0	3
TOTAL	25	--	XXX	0	25

PART FOUR - SUMMARY

RECAPITULATION

Table 3-4 presents a recapitulation of results derived from the comparative analyses and evaluations in Parts Two and Three. In both categories the performance of devices using LOFR technology was patently superior in kind and degree to those using HIFR technology in each instance of comparison.

Table 3-4. Recapitulation of Results.

PARAMETER	POSSIBLE POINTS	RATINGS AWARDED HI	RATINGS AWARDED LO	POINTS AWARDED HI	POINTS AWARDED LO
Acquisition Capability in:					
Open Terrain	15	EVEN	EVEN	0	0
Foliated Terrain	35	--	XXX	--	35
Built-Up Areas	20	--	XXX	--	20
Radio Frequency Interference	5	--	XXX	--	5
False Alarm Rate	8	--	XXX	--	8
Target Identification	6	--	XXX	--	6
Human Factors	5	--	XXX	--	5
Training	3	--	XXX	--	3
Maintenance	3	--	XXX	--	3
TOTAL	100	--	XXX	--	85

TECHNOLOGY TRANSFERENCE

A logical question to ask is: Would HIFR capabilities be significantly improved to a point approaching those of

LOFR if LOFR advanced electronic innovations were incorporated into HIFR design? The answer to this question is no. Although the HIFR system developed would be greatly improved, it would still be LOS dependent and not capable of detecting targets immersed in foliage.

OTHER SURVEILLANCE DEVICES

A cursory inspection of the other ground surveillance techniques available to the commander show that none offer the unique flexible capability of detecting targets immersed in foliage to any appreciable extent. Both image intensifying night vision devices (NVD's) and forward looking infrared (FLIR) sensors are essentially LOS dependent although FLIR has a nominal foliage penetration capability if the target is "hot" enough to produce the temperature gradient required for detection at the ranges involved. However, FLIR technology does perhaps offer the best solution to open terrain dection.[100] "[FLIR] detection techniques . . . have now made it possible to provide a thermal imaging device which can give an [operator] . . . a directly viewable image of a scene in complete darkness."[101] It can do this, day or night, in a completely passive mode without advertising its presence. This represents the ultimate objective of all surveillance development, the capacity to reliably detect a potential enemy without revealing one's own position in the process.[102] Lastly, unattended ground sensors (UGS) do not use the radar

but some other medium to detect targets.[103] UGS are not suited for fluid ground surveillance battlefield employment because of the time required for installation, the need to place them in the area of interest (often enemy held), and their lack of flexibility once implanted.[104] Therefore, of all the devices polled, only the LOFR system offers the commander a viable, usable capability to see targets masked by foliage or man-made obstacles in a fluid combat situation.

CHAPTER III

ENDNOTES

[1] See page 5, "ASSUMPTIONS."

[2] George W. Gehr, CPT., AN/PPS-5, Improvement Kit and R2010 Battlefield Surveillance Radar Report (Ft. Hood: MASSTER, 1972), v; see also (C)MASSTER II Test Report(U) (Ft. Hood: MASSTER, 1970), 44; see also (C)Physical Security Test Report(U), Vol. II (Ft. Hood: MASSTER, 1971), 19,20.

[3] Thomas E. Mendel, LTC, and others, MASSTER V Test Report (Ft. Hood: MASSTER, 1973), 34,36.

[4] Ibid., 35; see also Physical Security Test Report, 19.

[5] Ibid., D-9.

[6] Paul H. M. LaBay, III, MAJ, (C)Camp Sentinel Radar III (CSR III) Test Report(U) (Ft. Hood: MASSTER, 1971), 36; see also James H. Banks and others, Elements of a Battalion Integrated Sensor System: Operator and Team Effectiveness, Research Report 1187 (Arlington: U.S. Army Research Institute for the Behavioral and Social Sciences, 1975), 26.

[7] William L. Emery, Moving Platform FOPEN Radar Prototype Development (Aberdeen Proving Ground: ALWL, 1974), 3, 173.

[8] Louis V. Surgent, Jr., Evaluation of the Multipurpose Foliage Penetration Radar (M-FOPEN) in Hawaii (Aberdeen Proving Ground: ALWL, 1974), 2,33 to 35; see also LaBay, 9, 16,26; see also TWX 211608ZJUL70, ATMAS-STN-COM, (C)Final Test Report, Listening Post Surveillance Device (LPSD), AN/PPS-14 (MAE)(U) (Ft. Hood: MASSTER, 1970), 13,15.

[9] LPSD, AN/PPS-14, 15,16; see also Physical Security Test Report, 19.

[10] Ibid., 14; see also Surgent, M-FOPEN in Hawaii, 22; see also LaBay, 36.

[11]LaBay, 9; see also Surgent, M-FOPEN in Hawaii, 25.

[12]Ibid., 1,3; see also Louis V. Surgent, Jr., Foliage Penetration Radar: History and Developed Technology (Aberdeen Proving Ground: ALWL, 1974), Appendix D; see also Surgent, M-FOPEN in Hawaii, 39.

[13]Ibid., 36; see also Surgent, M-FOPEN in Hawaii, 19.

[14]Ibid., 36; see also Surgent, M-FOPEN in Hawaii, A-2.

[15]Mischa Schwartz and Leonard Shaw, Signal Processing, Discrete Spectral Analysis, Detection, and Estimation (New York: McGraw-Hill, Inc., 1975), 3,4.

[16]LaBay, 8,11.

[17]Ibid., 16,36.

[18]Field Manual 31-100 (TEST), Surveillance, Target Acquisition and Night Observation (STANO) Operations, 20 May 1971 (Washington: Government Printing Office, 1971), 3-7.

[19]LaBay, 36. The author observed this phenomena numerous times over a three period when testing HIFR systems.

[20]MASSTER II Test Report, 27.

[21]LaBay, 1; see also LPSD, AN/PPS-14, 3; see also Surgent, M-FOPEN in Hawaii, 6.

[22]Surgent, History and Developed Technology, Appendix D.

[23]Surgent, M-FOPEN in Hawaii, 33; see also LaBay, 34 to 36.

[24]MASSTER II Test Report, A-230, A-231; see also Banks, 60; see also LaBay, 16; see also (C)AN/TPS-58 (RATAC) Test Report(U) (Ft. Hood: MASSTER, 1972), 73.

[25]Surgent, M-FOPEN in Hawaii, 27,33; see also LaBay, 36.

[26] Ibid., 33, B-3; see also LaBay, 11,13,19,36; see also (C)Long Range Ground Surveillance Radar (LRGSR), AN/TPQ-34(U) (Saigon: ACTIV, 1970), II-19.

[27] LaBay, 16.

[28] Ibid., 3,36.

[29] Reference Book 30-6, Intelligence Systems Factbook (Ft. Leavenworth: USACGSC, 1976), 4-2.

[30] Surgent, M-FOPEN in Hawaii, 22; see also LRGSR, AN/TPQ-34, II-19, II-20.

[31] Ibid., 32; see also LaBay, 21.

[32] Ibid., 32; see also LaBay, 22,23.

[33] Ibid., 33; see also LaBay, 14; see also Physical Security Test Report, 19.

[34] Author's note: This situation occurred frequently during daylight testing of the Camp Sentinel Radar III and Multipurpose Foliage Penetration Radar where they were evaluated side-by-side with an AN/PPS-5A radar.

[35] LaBay, 13,30; see also Surgent, M-FOPEN in Hawaii, 6.

[36] Chart, Electronic Countermeasures Spectrum (Rolling Meadows, Il.: The Hallicrafters Co., 1969).

[37] Reference Book 100-5-1, Operations (Ft. Leavenworth: USACGSC, 1976), 14,15.

[38] Robert L. Graham, LTC, USA, and LTC Ray "M" Franklin, USMC, "MOBA," U.S. Army Aviation Digest, Vol. 22, No. 2 (Washington: Government Printing Office, 1976), 4.

[39] Paul Bracken, "Urban Sprawl and NATO Defense," Survival, Vol. XVIII, No. 6 (London: International Institute of Strategic Studies, 1976), 254.

[40] Alexander Woods, Jr., MAJ, "Combat-in-Cities," U.S. Army Aviation Digest, Vol. 22, No. 12 (Washington: Government Printing Office, 1976), 24; see also Graham and Franklin, 5.

[41] Ibid., 25; see also Reference Book 100-5-1, 14-18, 14-19.

[42] Ibid., 25.

[43] Graham and Franklin, 6.

[44] Bracken, 257.

[45] Ibid., 255 to 260.

[46] Graham and Franklin, 4.

[47] Field Manual 31-50, Combat in Fortified and Built-Up Areas, 10 March 1964 with changes (Washington: Government Printing Office, 1964), 29,32,38,52.

[48] Surgent, M-FOPEN in Hawaii, 36; see also Surgent, History and Developed Technology, 56.

[49] Surgent, M-FOPEN in Hawaii, 29. Author's note: The set was positioned 10 meters away from a high tension power line.

[50] Field Manual 32-30, Electronic Warfare: Tactics of Defense, 31 August 1976 (Washington: Government Printing Office, 1976), 4-1 to 4-8.

[51] Banks, 60; see also Gehr, iv, v; see also LaBay, 36; see also MASSTER II Test Report, A-237.

[52] Gehr, 1-10.

[53] LaBay, 36.

[54] Surgent, M-FOPEN in Hawaii, 17; see also LaBay, 10, 13.

[55] Ibid., 27; see also LaBay, 30.

[56] Author's note: Several tactical FM radios were usually at the radar to control various aspects of a test. They were used constantly to maintain contact with the installation range control, control target iterations, update target locations, and receive test data.

[57]Surgent, M-FOPEN in Hawaii, 27; see also LaBay, 10.

[58]Ibid., 29.

[59]See page 6, "DEFINITIONS."

[60]Schwartz and Shaw, 4,5; see also Encyclopedia of Science and Technology, 221.

[61]Emery, 3,173. For a description of different types of foliage, see the discussion starting on 182.

[62]Simon Haykin and Chris Hawkes, "Adaptive Digital Filtering for Coherent MTI Radar," Information Services, Vol. 11 (New York: American Elsevier Publishing Co., Inc., 1976), 333,334.

[63]Ibid., 346,357; see also M. I. Skolnik, Introduction to Radar Systems (New York: McGraw-Hill Co., 1962), 17 to 26.

[64]MASSTER II Test Report, 21,74.

[65]Surgent, M-FOPEN in Hawaii, v, 19,33,37; see also LaBay, 13; see also LPSD, AN/PPS-14, 18; see also Physical Security Test Report, 19.

[66]Ibid., 39; see also LaBay, 3.

[67]Ibid., 19; see also LaBay, 16.

[68]LaBay, 9; see also LPSD, AN/PPS-14, 14,21.

[69]Mendel, D-9, D-36; see also MASSTER II Test Report, A-201; see also Banks, 4.

[70]Ibid., 34.

[71]Banks, 28,51,54; see also Surgent, M-FOPEN in Hawaii, 26,27.

[72]Ibid., 49.

[73]Surgent, M-FOPEN in Hawaii, 19,33; see also LaBay, 9,21.

[74]Ibid., 19; see also LaBay, 3,26,33.

[75]LaBay, 9,13,20.

[76]Reference Book 30-6, 4-2; see also Field Manual 31-100, 11-10; see also "ARI - a new name, a new approach," Army Research and Development News Magazine, Vol. 13, No. 8 (Washington: U.S. Army R&D Info ation Systems Office, 1972), 25.

[77]MASSTER II Test Report, 77, A-231; see also Mendel, D-9; see also Gehr, 2-14; see also AN/TPS-58 Test Report, 64,72; see also Physical Security Test Report, 19, A-26.

[78]Ibid., A-230; see also AN/TPS-58 Test Report, 73.

[79]Field Manual 31-100, 11-1.

[80]Surgent, M-FOPEN in Hawaii, 29,36; see also LaBay, 10

[81]Ibid., 31,36; see also LaBay, 10; see also LPSD, AN/PPS-14, 21.

[82]Ibid., 36; see also LaBay, 10,33; see also LPSD, AN/PPS-14, 20.

[83]Ibid., 29, B-3; see also LaBay, 10,33; see also LPSD, AN/PPS-14, 19.

[84]Comments of MG Paul F. Gorman, DCS for Training, Headquarters, TRADOC, on 2 February 1977 at a seminar on training effectiveness analysis for personnel of CACDA, Ft. Leavenworth, Kansas.

[85]Field Manual 31-100, 11-5.

[86]Ibid., 11-1; see also Banks, 47,60; see also MASSTER II Test Report, 77.

[87]Army Regulation 611-201, Enlisted Career Management Fields and Military Occupational Specialities, 9 July 1976 with changes (Washington: Government Printing Office, 1976), 3-96-3, 3-96-31, 3-96-32.

[88]Surgent, M-FOPEN in Hawaii, 37; see also LaBay, 13.

[89]LPSD, AN/PPS-14, 14,20.

[90]LaBay, 10.

[91]Telephonic interview with Doctor Phillip C. Dickinson, Deputy Director, and COL Sammy J. Cannon, Battlefield Systems Integration Directorate, Headquarters, DARCOM, on 13 January 1977.

[92]Banks, 60; see also Gehr, 2-16, 2-17; see also Mendel, D-10, D-34; see also MASSTER II Test Report, A-203.

[93]Reference Book 30-6, 4-2.

[94]Mendel, D-36, C-4-3; see also MASSTER II Test Report, 78, A-204, A-235.

[95]Author's note: During comparison testing of the AN/PPS-5A against the Camp Sentinel Radar III and Multipurpose Foliage Penetration Radar, troop support units were required to keep several AN/PPS-5A radar sets readily available to insure uninterrupted testing.

[96]For specific details on Radar Sets, AN/PPS-5 and 5A, see the Technical Manual 11-5840-298-XX series; for specific details on the Radar Set, AN/TPS-58, see the Technical Manual 11-5840-348-XX series.

[97]Surgent, M-FOPEN in Hawaii, 33,36,B-4; see also LaBay, 10,13; see also LPSD, AN/PPS-14, 18.

[98]Ibid., 33; see also LaBay, 10,13; see also LPSD, AN/PPS-14, 18.

[99]Ibid., 36, B-4; see also LaBay, 10.

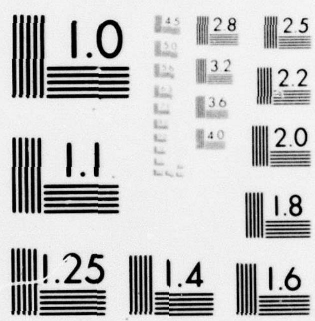
[100]Dan Boyle, "Thermal Imaging - Rapid Growth in Night Vision," International Defense Review, Vol. 9, No. 6 (Geneva: Interavia S. A., 1976), 996, 998.

[101]Ibid., 997.

[102] Ibid.

[103] Unattended Ground Sensor Devices, Sup R 02712 (Ft. Huachuca: USAICS, 1976), Chapters 2,3,6 and 10 describe current UGS available to the commander.

[104] Reference Book 30-6, 3-1, Table 3-1.



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based on the above discussions it is concluded that:

1. The LOFR system demonstrates a marked superiority in kind and degree over its HIFR counterpart to acquire targets of military interest in foliated and built-up areas. In open areas both systems perform equally well.

2. At present the ranging capabilities of HIFR systems are superior to those of comparable LOFR systems.

3. In open areas, the high mast and large antenna of the LOFR system make it susceptible to enemy observation and subsequently neutralization or avoidance.

4. The LOFR system is much less vulnerable to spurious radio frequency interference than its HIFR counterpart.

5. Advanced electronic design permits the LOFR system to better cope with and adjust to degrading external environmental conditions, thus increasing its inherent acquisition capability.

6. LOFR systems experience substantially fewer false alarms than comparable HIFR systems.

7. Operators using LOFR systems are able to correctly identify targets at a rate of better than three to one over their HIFR counterparts.

8. LOFR systems permit operators to discern false, spurious targets more quickly and accurately in uncontrolled areas than HIFR systems do.

9. LOFR systems enhance the human factors aspects normally associated with tedious HIFR operation by concomitantly reducing operator fatigue and increasing his productive work span.

10. The LOFR system's simplified method of operation and repair reduces overall training requirements for operators and repairmen. It expands the Army's potential manpower pool from which these personnel are drawn. It also facilitates the integration of LOFR systems at maneuver levels comparable to or lower than those of currently fielded HIFR systems.

11. HIFR systems are a standard item of equipment in the Army inventory whereas there are no plans pending to introduce a LOFR system into the Army inventory.

12. The foliage penetration LOFR system enables the commander to better observe more of the battlefield than its line-of-sight dependent HIFR counterpart.

13. The LOFR system provides the commander with the preemptive opportunity to detect and engage hostile targets in foliated or built-up areas before the enemy can bring its direct fire weapons fires to bear on friendly formations.

14. Of the two systems considered, the LOFR system offers the best practical solution to optimizing the Army's ground surveillance radar capability.

RECOMMENDATIONS

It is recommended that:

1. The U.S. Army reexamine its current position on ground surveillance radar application by investigating the full potential offered by low frequency radar technology.

2. The U.S. Army place its priority effort into developing low frequency radar systems to enhance its future battlefield ground surveillance radar capability.

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